# Training for tactical operations in tropical environments: Challenges, risks, & strategies for risk management

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# Science of Sport, Exercise and Physical Activity in the Tropics

Conference Proceedings

JAMES COOK UNIVERSITY

2016

Conference proceedings
Townsville, Australia
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*At James Cook University, we acknowledge the Australian Aboriginal and Torres Strait Islander peoples of this nation. We acknowledge the Traditional Owners of the lands on which our campuses and study centres are located and where we conduct our business. We pay our respects to ancestors and Elders, past, present and future. JCU is committed to honouring Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, waters and seas and their rich contribution to JCU and society.*

# WELCOME

*Dear delegate,*

*We welcome you to Townsville for the second 'Science of Sport, Exercise and Physical Activity in the Tropics' conference. A unique and exciting program has been developed that encompasses the interests of sport, exercise and physical activity within tropical climates.*

*The conference starts with a social evening with local sport scientists, followed by two days of speakers, both local and from abroad. Key speakers will provide exclusive perspectives on environmental physiology, occupational and military foci, sports, and clinical exercise physiology.*

*Additionally, delegates have a significant opportunity to highlight their individual research and engage in networking during the many breaks and social gatherings.*

*The program offers great opportunities to hear the latest scientific developments from world-renowned experts and a great opportunity to share scientific evidence with key personnel interested in, or working in conditions akin to tropical environments.*

*On behalf of the Sport & Exercise Science discipline at James Cook University, we welcome you to the tropical experience of North Queensland and hope you enjoy your conference and stay!!*

*Associate Professor Anthony Leicht*

# Keynote Speakers

**Professor Craig Crandall – *University of Texas Southwestern Medical Center, Texas Health Presbyterian Hospital Dallas***

Craig Crandall completed a Doctorate in Physiology at the University of North Texas Health Science Center as well as a post-doctoral fellowship at the University of Texas Health Science Center at San Antonio. He is a Professor of Internal Medicine at the University of Texas Southwestern Medical Center as well as the Director of the Thermal and Vascular Physiology Laboratory at the Institute for Exercise and Environmental Medicine – Texas Health Presbyterian Hospital Dallas. He mentored 19 post-doctoral fellows and has received over $10 million in extramural grant support where he is the PI.

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**Dr Olivier Girard – *University of Lausanne***

After completing his Doctoral Degree (2006) in Human Movement Sciences at Montpellier University in France, Dr. Olivier Girard has been working (2008-2014) as a Research Scientist at Aspetar – Orthopaedic and Sports Medicine Hospital in Qatar. Currently he is working at Lausanne University in Switzerland. His actual researches are mainly concerned with the impact of an environmental stress on neuromuscular fatigue development and the relevance of altitude training for team-sport athletes. They articulate around the importance of neuro-mechanical, metabolic and cardiorespiratory adjustments in response to high-intensity, intermittent locomotor exercises (repeated sprints) performed in stressful conditions (high temperature and/or elevated altitude). He has published over 75 articles in peer-reviewed journals.

**Associate Professor Rod Pope – *Bond University***

Rod Pope is an Associate Professor of Physiotherapy and co-leads the Tactical Research Unit at Bond University, Australia. Rod consulted to the Australian Department of Defence for 17 years and established and led the ADF's Defence Injury Prevention Program, 2000-2006. In this role, he worked closely with senior military physical training instructors to optimize physical training practices in the ADF, Australia-wide. Rod continues to conduct and supervise wide ranging research and consultancy projects on preventing injuries and enhancing performance during physical activity, across various tactical training and operational contexts.

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**Associate Professor Nigel Taylor – *University of Wollongong***

Nigel has over thirty years of research experience in human stress physiology, with particular emphases upon environmental and exercise physiology, and in particular, human temperature regulation. He has published more than 100 refereed journal manuscripts, seven monographs and over 30 chapter contributions. He is the Reviews Editor for the European Journal of Applied Physiology, and is an International Editorial Board member of nine other refereed journals. He is the immediate past Chair of the Section on Thermal Physiology (International Commission on Comparative Physiology) of the International Union of Physiological Sciences.

# Invited Speakers

**Dr Mohammed Ihsan Abdullah – *Singapore Sports Institute***

Dr Mohammed Ihsan is a Sport Physiologist with the Singapore Sports Institute. His research interests centre on applied human physiology and exercise performance, with a focus on muscle physiology, thermoregulation, physiological recovery and training adaptations.

He is actively researching the use of cold/heat therapy on fatigue, performance and physiological adaptations to training. In his current position, Dr Ihsan also works with sports such as Field Hockey, Seven's Rugby, Badminton and Pencak Silat.

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**Dr Matt Brearley – *Thermal Hyperformance***

Dr Matt Brearley holds a PhD in Thermal Physiology and was the heat specialist of the 2008 Australian Olympic team in Beijing, China prior to focusing on occupational heat stress. Matt established a research program with the National Critical Care and Trauma Response Centre, developing evidence based procedures to maximise worker health, safety and performance in the heat. Matt provides heat stress mitigation services based upon this evidence to a wide range of industries including mining, construction, oil and gas transportation, electrical utilities and emergency services.

**Dr Andrew Hunt – *Defence Science and Technology Group***

Dr Hunt's research interests focus on human health and performance in extreme environments. Dr Hunt completed his PhD studies of the heat strain experienced by surface mine workers at the Queensland University of Technology before commencing as a thermal physiologist for the Defence Science and Technology Group. In this role he has conducted research into the development of novel solutions for enhancing the operational capabilities of the individual combatant through the vast array of environments to which military personnel may be exposed. Specifically he has addressed the physiological tolerance of military personnel to operations in the heat, the risk management of heat-related illnesses, the influence of protective clothing systems such as body armour and chemical & biological protection on body heat loss, human performance in cold weather operations, the physiological effects of decompression and hypoxia in aircraft, and the development of physical employment standards. Dr Hunt's presentation will discuss the unique challenges to human performance in extreme environments that are posed by military training and operational activities.

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**Dr Ollie Jay – *University of Sydney***

Ollie is Director of the Thermal Ergonomics Laboratory in the Faculty of Health Sciences (Exercise and Sport Science) and a member of the Charles Perkins Centre (CPC) at the University of Sydney. Prior to his arrival in Australia in January 2014, he was a tenured Associate Professor in the School of Human Kinetics at the University of Ottawa, Canada (2008-2013). Ollie's research activities primarily focus on developing a better understanding of the physiological and physical factors that determine human heat strain during work and/or physical activity, as well as among the general population during heat waves.

To date, Ollie has published 75+ peer-reviewed journal articles and has received funding from the Natural Sciences and Engineering Research Council of Canada, MS Research Australia, National Football League (NFL) Charities, and the US National Academy of Sciences. He is a Fellow of the American College of Sports Medicine (ACSM) and former Chair of the ACSM Environmental and Occupational Physiology Interest Group.

**Professor David Pyne –** ***Australian Institute of Sport***

Professor David Pyne is a sports scientist in the Department of Physiology at the Australian Institute of Sport (AIS). Pyne has 25 years' experience at the AIS and been involved with every Australian Olympic Swimming Team from Seoul, 1988 to London, 2012. He has extensive experience with basketball, rugby union, rugby league, Australian Football, cricket and swimming at the AIS and national levels. His work in the areas of exercise and the immune system, the applied physiology of swimming, and fitness and conditioning for team sports is recognised internationally. Professor Pyne has published over 190 peer-reviewed papers and holds Adjunct Professor appointments at the Faculty of Health, University of Canberra, and the Griffith Health Institute, Griffith University.

He was Foundation Editor of the International Journal of Sports Physiology and Performance from 2004-2009 and currently serves as the Consulting Editor. Professor Pyne is a member of Sports Medicine Australia, and a Fellow of the American College of Sports Medicine. He values equally the metrics of a publication record, hard-earned experience and street smarts to maintain relevance in elite sport.

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**Associate Professor Ian Stewart –** ***Queensland University of Technology***

Associate Professor Ian Stewart is a Director of Research and Program Leader at the Queensland University of Technology. A/Prof Stewart's research focusses on environmental and occupational physiology. He has attracted in excess of $5.5 million in funding investigating environmental issues in the mining and security industries as well as police/military organisations. This work has seen the development of national operating procedures in the area of heat stress management, as well as multiple publications and reports to industry and government organisations. He has also served as an expert witness in industrial court cases.

# Conference awards

Presenting delegates have the opportunity of winning one of two awards at this conference.

- **Young Investigator Award** (sponsored by Human Kinetics)
    - $400 Human Kinetics gift certificate

- **Conference Best Presentation** (sponsored by Exercise & Sports Science Australia)
    - $500 prize

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# Conference Program

## WEDNESDAY September 7

| Start | End | FOYER |
|---|---|---|
| 4:30 PM | 6:30 PM | **REGISTRATION** |
| 6:30 PM | 8:30 PM | **WELCOME RECEPTION**<br>- guest speaker from the NQ Cowboys’ staff |

## THURSDAY September 8

| Start | End | Room 1 – Raffles | Room 2 – Kingston |
|---|---|---|---|
| 8:45 AM | 9:00 AM | **OPENING ADDRESS** | |
| 9:00 AM | 10:00 AM | **Assoc/Prof Nigel Taylor:** How humans adapt to exercising and working in the tropics | |
| 10:00 AM | 10:30 AM | **MORNING TEA** | |
| 10:30 AM | 11:30 AM | **Dr Olivier Girard:** Neuro-mechanical adaptations to environmental stress in team sports | |
| 11:30 AM | 12:30 PM | **Dr Matt Brearley:** Preliminary evidence of a heat hangover, a new heat illness classification for occupational settings? | |
| 12:30 PM | 1:30 PM | **LUNCH** | |
| 1:30 PM | 3:00 PM | **Free Oral Presentations 1**<br>**1) Nicholas Ravanelli:** The influence of aerobic training on maximum skin wettedness and its effects during uncompensable heat stress. **2) Frank Marino:** Short time trial performance of trained and untrained men in two environmental conditions. **3) Jared Coleman-Stark:** Dose-response effects of ambient temperature on resistance training outcomes in elite weightlifters. **4) Rachel Gale:** Effect of short-term heat training on intermittent running performance in a temperate environment in team sport players. **5) Naroa Etxebarria:** Dissociation between physiological and perceptual markers in short-term heat training: a case study. | **Free Oral Presentations 2**<br>**1) Joshua Guy:** Immediate post-exercise cooling following heat acclimation training improves cycling performance. **2) Mohamad Haiyum:** The metabolic and cardiovascular demands of Singapore firefighting breathing apparatus proficiency test. **3) Mike Climstein:** Lifetime prevalence of non-melanoma and melanoma skin cancer in Australia surfers. **4) Terry Engelberg:** Crime in the Tropics: Is sport part of the solution, or part of the problem? **5) Patrick Miniti:** Teaching physical education to ECE learners through the use of the coconut tree and the ECE Games. |
| 3:00 PM | 3:30 PM | **AFTERNOON TEA** | |
| 3:30 PM | 4:30 PM | **JCU-Sport and Exercise Science Research**<br>**1) Leesa Pearce:** Officiating role influences the physical match activity profiles of rugby league touch judges and referees. **2) Carl Woods:** Synchronous league-wide evolution of game-play in the Australian Football League from 2001-2015: Implications for performance analysis in team sports. **3) Sarah Gaudion:** Identifying the physical fitness, anthropometric and athletic movement qualities discriminant of developmental level in elite junior Australian football. **4) Kenji Doma:** The repeated bout effect of strength training across three bouts. **5) Anthony Leicht:** Team performance indicators can explain success for men’s basketball at the Olympics | **Assoc/Prof Ian Stewart:** Assessing hydration status in occupational athletes: challenges faced and lessons learnt |
| 4:30 PM | 5:00 PM | | |

## FRIDAY September 9

| Start | End | Room 1 – Raffles | Room 2 – Kingston |
|---|---|---|---|
| 9:00 AM | 10:00 AM | **Prof Craig Crandall:** Thermoregulation in healthy and diseased/injured humans | |
| 10:00 AM | 10:30 AM | **MORNING TEA** | |
| 10:30 AM | 11:30 AM | **Assoc/Prof Rod Pope:** Training for tactical operations in tropical environments: challenges, risks, & strategies for risk management | |
| 11:30 AM | 12:30 PM | **Dr Ollie Jay:** Assessing and understanding thermoregulatory impairments in specific populations | |
| 12:30 PM | 1:30 PM | **LUNCH** | |
| 1:30 PM | 2:30 PM | **Free Oral Presentations 3**<br>**1) Georgia Chaseling:** Cold fluid ingestion extends exercise capacity of heat-sensitive individuals with Multiple Sclerosis in a warm environment. **2) Jacinta Saldaris:** The effect of crushed ice ingestion on endurance performance and cognitive function in hot and humid conditions. **3) Matthew Zimmermann:** Crushed ice ingestion does not improve female cycling time trial performance in the heat. **4) Grant Landers:** Caffeinated ice slushy enhances endurance cycle performance in hot, humid conditions. | **Free Oral Presentations 4**<br>**1) Samuel Chalmers:** Short-term heat acclimation and the lactate threshold. **2) Jemma Preece:** Thermal effect of topical menthol on short duration cycling performance in the heat. **3) Kahlia Perry/Clare Goss:** Effect of Kinesio Tape on thermoregulation during submaximal cycling: a pilot study. **4) Lee Taylor:** Pre-match and half-time-cooling on simulated soccer (iSPT) performance at 30°C |
| 2:30 PM | 3:30 PM | **Prof David Pyne:** Effects of heat on sports performance | **Dr Andrew Hunt:** Military training in hot environments: identifying future directions to enhance individual health and physical performance |
| 3:30 PM | 4:00 PM | **AFTERNOON TEA** | |
| 4:00 PM | 4:30 PM | **Keynote panel: THE FUTURE**<br>Assoc/Prof Nigel Taylor, Dr Olivier Girard, Prof Craig Crandall, Assoc/Prof Rod Pope | |
| 4:30 PM | 5:00 PM | **Awards & Closing address** | |
| 6:15 PM | 6:45 PM | *Pre-Dinner drinks* | |
| 7:00 PM | 11:00 PM | **GALA DINNER** | |

*Thursday 8th September*
*Chairperson: Anthony Leicht*
*Room 1 – Raffles*

## How humans adapt to exercising and working in the tropics

**Nigel AS Taylor**
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**Introduction: our heritage**
Human migration to Australia occurred over 62,000 years ago. Those first Australians established one of the oldest continuous populations on the driest of the inhabited continents, surviving the world's longest drought (>10,000 y). Indeed, the traditional owners established a cultural identity and sustainable lifestyle thousands of years before any of the more recognised ancient civilisations. However, our temperature and rainfall variations belie the national stereotype, with temperatures from -23ºC (Charlotte Pass, New South Wales) to 50.7ºC (Oodnadatta, South Australia), and annual rainfalls from 125 mm (Lake Eyre, South Australia) through to 12,461 mm in the tropical north-east (Bellenden Ker, Queensland). Those climates shaped the variability, quality and quantity of the flora and fauna, and provided unique and diverse adaptation opportunities that influenced the cultural, lifestyle and physiological characteristics of the Aborigines.

Until the first European settlements (1788), the traditional owners lived in isolation. The early settlements in Sydney Cove were soon extended to the mostly temperate, coastal climates of Norfolk Island, Tasmania, Port Macquarie and Moreton Bay. However, free settlers rapidly spread across the continent, and following Federation (1901), Australia's first medical research institute was established (1908): the ***Australian Institute for Tropical Medicine*** (now at James Cook University). One of its founding objectives was to evaluate the physiological consequences of the *Immigration Restriction Act* (1901; the white Australia policy), the outcome of which was that Europeans had to perform physically demanding jobs in tropical climates, resulting in significant heat-illness. The first directors of that institute (A. Breinl [1908-1920] and R.W. Cilento [1922-1928]) were perhaps Australia's first human, thermal physiologists[6]. The foundation for this presentation will be set upon this combined heritage, with the principal objective being to provide insights into thermal adaptation in the tropics[4].

**The problem with the tropics**
From a climatic perspective, it is the air temperature and water vapour pressure that present the greatest challenges. Thermal physiologists determine the likely physiological impact of environmental conditions using rational heat-strain scales that are based on the *First Law of Thermodynamics*. One such derivation is the *Heat-Strain Index*[1], which can be used to quantify the compensability of working conditions. For instance, for individuals performing 100 W of external work with 65% of the skin uncovered, in an air temperature of 35ºC and a water vapour pressure of 4.78 kPa (relative humidity 85%), the heat-strain quotient will be 1,674. Since values >100 are considered uncompensable, moderate-hard physical work is prohibitive in these conditions for the unadapted, leading to unregulated (forced) hyperthermia, and eventually to heat illness.

**Ethnic differences: Aboriginal and tropical residents**
Physiological adaptation is almost invariably associated with a reduced (blunted) sensitivity of the effector responses to a given stimulus, and thereby reducing physiological strain during subsequent stress exposures. A classical example is the blunted or habituated metabolic reaction of the traditional-living Aborigines to cold stress, relative to non-adapted Caucasians[3], although we know little about their tropical-heat tolerance. In this regard, more is known about the thermal adaptation of our Asian neighbours[3,4], with apparent ethnic differences not reflecting inherited (genotypic) variations, but acquired (phenotypic) adaptations, that increase heat tolerance and elevate the safety margin during thermal-stress loading.

The progression from "*mad dogs*" to "*permanent summermen*" is triphasic in nature[4,5] in both tropical indigenes and Europeans, although most short-term, heat-adaptation research was not continued through to the final phase, leading to some misinterpretation of the available evidence. The acute response phase is characterised by work intolerance, with a significantly elevated risk of heat illness (phase one). This intolerance is, however, most frequently expressed in the form of cardiovascular insufficiency; a failure to adequately regulate blood pressure[4]. With repeated heat exposure, healthy individuals elevate their autonomic heat-loss responses (phase two). This is most apparent for sudomotor function, which reveals a lower sweat onset threshold, a greater sensitivity and an elevated peak secretion rate. However, several cardiovascular adaptations precede, and even facilitate, sudomotor adaptation. For instance, the plasma volume is elevated to buffer against both sweat losses and the obligatory cutaneous vasodilatation. In most climates, but particularly within humid-heat, profuse sweating is ineffective and wasteful. Therefore, within both indigenes and other long-term tropical residents, one finds clear evidence of sudomotor habituation (phase three), with much less prolific sweating in the heat.

**Integrated thermal adaptation**

The primary functional adaptations to repeated humid-heat exposure are designed to support both thermal and cardiovascular homoeostasis when exposed to the heat. Those mechanisms of adaptation will be developed in detail within this presentation, and will include changes within body-fluid balance, central cardiac function, peripheral vasomotor responses, heat production, sudorific function and deep-body temperatures[4]. The possibility of morphological adaptation will also be introduced. As an *entrée* to those discussions, adaptation theory will be described, as an understanding of those concepts is essential to both the experimental and practical application of heat adaptation. That discussion will include the following topics: physiological overload, adaptation thresholds, the adaptation impulse, adaptation forcing functions and their progression, adaptation specificity and adaptation decay[4,5].

**The practices of heat adaptation**

Several methods for inducing heat adaptation will be presented[5], including their historical development[4]. Whilst pure physiologists wish to emphasise the mechanisms of adaptation, applied scientists have more pragmatic interests, such as the preparation of workers and athletes to tolerate known working and climatic conditions. These need not be mutually exclusive objectives, but previous and repeated failure to differentiate between those purposes has led to both an over-simplification and misinterpretation of the scientific evidence. Two heat-adaptation practices will be explored in detail: the traditional (constant stress) model and the controlled hyperthermia (constant strain or isothermal) method. For workers (*e.g*., military and emergency service personnel), the former method is acceptable and most commonly used, but for investigating the mechanism of thermal adaptation and for the preparation of athletes, the latter method is recommended, although that approach has infrequently been adopted.

**Adaptation avoidance**

Finally, it is curious to observe that, within a century, we have moved from a position of seeking knowledge concerning the enhancement of human heat tolerance through stress exposure and adaptation, to an endemic state of strain minimisation, with an almost complete prevention of stressful exposures in some individuals. Yet, over many thousands of years, repeated encounters with a broad array of internal and external stresses led to the acquisition of the broadly adapted state in humans; biological generalists[4]. Those attributes were relayed to succeeding generations, either epigenetically or through natural selection. However, many contemporary behavioural practices in the home and at work now prevent people from experiencing the stresses that would have ensured their survival during another era. Since those adaptations, or the lack thereof, can be transferred epigenetically to the next generation, one wonders how modern, first-world humans may survive within less pleasant circumstances.

**Conclusion**

A unifying theme within this communication will be adaptation specificity. That is, the nature of the adaptation stimulus will largely dictate the form of the resulting physiological adaptation and its transference to, and protection from, other stresses. This is true for all who live, work and play in hot-humid regions. It is perhaps more pertinent to the participants of heat-adaptation research and those who undertake heat adaptation to reduce occupational strain or to enhance athletic performance. It is both fitting and relevant to conclude with a quote from another past scientist from the ***Australian Institute for Tropical Medicine*** (E.S. Sundstroem)[2]:

"*It is conceivable that individuals may not be all alike in their choice of the acclimatization mechanisms which nature has placed at their disposal.*"

**References**


1. Belding HS, Hatch TF. 1955. Index for evaluating heat stress in terms of resulting physiological strain. Heat Piping and Air Conditioning 27:129-136.
2. Sundstroem, ES. 1927. The physiological effects of tropical climate. Physiological Reviews. 7:320-362.
3. Taylor NAS. 2006. Ethnic differences in thermoregulation: genotypic versus phenotypic heat adaptation. Journal of Thermal Biology 31:90-104.
4. Taylor NAS. 2014. Human heat adaptation. Comprehensive Physiology 4:325-365.
5. Taylor NAS, and Cotter JD. 2006. Heat adaptation: guidelines for the optimisation of human performance. International SportMed Journal 7:33-57.
6. Taylor NAS, Taylor EA, Maloney SK, and de Dear RJ. 2016. Contributions from a land down under: the arid continent. In: History of Thermal Physiology, Blatteis, CM. edt, American Physiological Society. *In press.*

*Thursday 8th September*
*Chairperson: David Pyne*
*Room 1 – Raffles*

## Neuro-mechanical adaptations to environmental stress in team sports

**Olivier Girard**
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**Introduction**
As a primary effect of globalization, the incidence of major sport events in hot environments (2016 Olympics) or at altitude (2010 FIFA World Cup) has increased and many upcoming prestigious events will require athletes to compete in Equatorial and Middle Eastern regions. The ability to repeat sprints (*i.e*., repeated-sprint ability, RSA) is crucial to various team sports (*e.g*., Rugby, Australian Football League, Cricket). The physiological responses to (repeated)-sprint activity show a high degree of neuromuscular (*i.e*., neural drive determining maximal sprint velocity) and metabolic (*i.e*., limitations in energy supply and metabolic accumulation) stress. Comparatively, the biomechanical aspects of sprinting have generated less and more recent interest. In an attempt to gain a competitive edge, team-sport players from all around the world are now using altitude training more than ever before. The panorama of the hypoxic methods for team sports is now wider than in the past with the recent development of innovative methods to improve various aspects of in-game physical performance. This keynote lecture aims to (i) provide an overview of the acute effects of adverse environmental conditions (heat stress, hypoxia) on sprint performance and the potential underpinning mechanisms during single and multiple efforts, with special reference to neuro-mechanical manifestation of fatigue and (ii) present and discuss the recent updates on altitude/hypoxic training (advancements and limitations) for team sports.

**Sprint performance under challenging environmental conditions**
Improved single-sprint performance (*i.e*., mean and/or peak running speed or cycling power output) can be achieved following passive local muscle heating (*e.g*., warm baths and/or heated blankets), active warm-up, passive heating (*e.g*., elevation of core temperature), or hot ambient conditions (*e.g*., heat exposure prior to exercise including an active warm-up) presumably due to improved muscle contractility.[4] Under heat stress, elevations in skin/core temperatures are associated with increased cardiovascular and metabolic loads in addition to decreasing voluntary muscle activation; and there is compelling evidence to suggest that large performance decrements occur when repeated-sprint exercise (brief recovery periods, usually < 60 s) is performed in hot compared to cool conditions. Performance of a single sprint is generally not negatively affected by acute hypoxic exposure. Hence, an enhanced anaerobic energy release can compensate for the reduced aerobic ATP production during short maximal efforts in hypoxic conditions. However, RSA is more altered at high (> 3000-3500 m or $FiO_2$ below 13-14%) than lower altitudes, either normoxia or low-to-moderate (< 3000 m or $FiO_2$ above 14%) altitude.[2] Not only acute hypoxic exposure decreases convective $O_2$ transport (*i.e*., reduction in arterial $O_2$ saturation values), but also challenges multiple regulatory systems by increasing cardiorespiratory (*i.e*., higher heart rate, minute ventilation), metabolic (*i.e*., slower muscle re-oxygenation responses) and/or neuromuscular (*i.e*., incomplete muscle activation) requirements during sprinting or subsequent recovery periods.

**Neuro-mechanical determinants of sprint performance – new technology, new concepts**
During the 1990s, sprint treadmills have been developed to measure power during sprinting but were not without any associated drawbacks (*i.e*., force and velocity not measured at the same location, low sampling rate, measurement of the vertical but not horizontal forces, use of "flying starts"). The recent modification of an instrumented treadmill for sprint use (*i.e*., the so-called ADAL treadmill), which allows athletes to run and produce speed ''freely'', *i.e*., with no predetermined belt speed imposed, allows the continuous measurement of both valid and reproducible ground reaction forces during accelerated runs.[2] When eleven athletes randomly performed in cool (25°C, 45% rH) and hot (38°C, 21% rH) ambient conditions three sets of five 5-s sprints with 25-s recovery and 3 min between sets on the ADAL treadmill, distance ran in 5 s and propulsive power decreased from set 1 to set 3 (-7.0% and -14.2%; $p<0.05$), with lower values (-3.5% and -6.8%; $p<0.05$) in set 2 in hot *vs*. cool. In this later study, higher whole-body temperature and perceptual strain in the heat were associated with slightly larger alterations in running kinematics (mostly visible in set 2), but not kinetics. In order to evaluate the effects of different levels of altitude on running mechanics alterations during repeated treadmill sprinting, thirteen recreational team-sport athletes performed eight 5-s sprints with 25-s of passive recovery on an instrumented treadmill.[2] At a simulated altitude of ~3600 m, impairments in RSA and the magnitude of fatigue-induced kinetics and kinematics alterations exceed those observed near sea level or at ~1800 m. We further revealed that RSA is more impaired in hypoxia than in hot environment when compared to a control

condition.[5] However, the nature and extent of fatigue-induced alterations in running kinetics, kinematics and spring-mass characteristics did not differ between the three environmental conditions.

**Updated panorama of hypoxic methods**

Historically, altitude training emerged in the 1960s and was limited to the "Live High Train High" (LHTH) method for the endurance athletes looking for increasing their hemoglobin mass and the oxygen transport. This "classical" method was completed in 1990s by the "Live High Train Low" (LHTL) method where athletes benefit from the long hypoxic exposure and from the higher intensity of training at low altitude. Innovative methods were proposed recently as "Resistance Training in Hypoxia", "Remote Ischemic Preconditioning" or "Repeated Sprint Training in Hypoxia" (RSH), presumably with peripheral adaptations postponing muscle fatigue.[3] In youth highly trained football players, for instance, the addition of 10 repeated-sprint training sessions performed in hypoxia *vs*. normoxia to their regular football practice over a 5-week in-season period was more efficient at enhancing repeated-agility ability (including direction changes). RSH efficiency likely relates to the compensatory vasodilatory effects on fast twitch fibers behavior leading to an improved $O_2$ extraction by these fibers. Observations of greater amplitudes of muscle blood perfusion variations post-RSH, suggesting enhanced muscle blood flow, support the above hypothesis of a greater $O_2$ utilization by fast twitch fibers after this particular intervention.

The panorama of the hypoxic methods for team sports is now wider than in the past. Beyond all these recent improvements, a combination of different hypoxic methods can be used for maximizing the benefits and reducing the main drawbacks of each one. Compared to "traditional" LHTL, by combining LHTL and RSH ("Live High Train Low and High"; LHTLH) where athletes live high and train low except for few intense workouts in altitude additional benefits regarding RSA (twice larger gains that were maintained at least for 3 wk post-intervention) have been reported in elite field-hockey players, while gains in hemoglobin mass and in specific aerobic performance were similar.[1] The superiority of LHTLH to LHTL was further demonstrated by an up-regulation of the mRNA expression of factors implicated in the regulation of oxygen signaling and transport, mitochondrial biogenesis as well as enzymes of mitochondrial metabolism.

**Conclusion**

Many team-sport events are organized in hot environments or at altitude, so the understanding of the impact of heat stress and hypoxia on neuro-mechanical responses of players is paramount to improve competition preparation. The recent validation of an instrumented sprint treadmill made it possible to assess the instantaneous changes in both running velocity and ground reaction forces during maximal sprints similar to game play. Compared to control, performance and mechanical running alterations during repeated treadmill sprinting are impaired in severely hot and hypoxic environments. Altitude/Hypoxic training embraces a large range of different methods. "Classical" methods ("Live High Train High; LHTH" and "Live High Train Low; LHTL" with prolonged hypoxic exposure aim principally to increase the oxygen transport capacity. Recent innovative methods ("Repeated Sprint Training in Hypoxia; RSH" or "Resistance Training in Hypoxia; RTH) induce peripheral muscle adaptations postponing fatigue. Additionally, for team-sport athletes looking to elicit concurrent aerobic and anaerobic adaptations to improve sea-level performance, ''Live High Train Low and High'' hypoxic training is an attractive combination. Practical recommendations for implementation of these methods will also be discussed. For instance, mobile hypoxic inflatable marquees - directly located on the playing ground - are now available, opening new boundaries in future advancements of hypoxic training applications in team sports.

**References**


1. Brocherie F, Millet GP, Hauser A, Steiner T, Rysman J. Wehrlin J, and Girard O. 2015. ''Live High–Train Low and High'' Hypoxic Training Improves Team-Sport Performance. Medicine & Science in Sports & Exercise 47:2140-2149.
2. Brocherie F, Millet GP, Morin J-B, and Girard O. 2016. Mechanical alterations to repeated treadmill sprints in normobaric hypoxia. Medicine & Science in Sports & Exercise [Epub ahead of print]
3. Girard O, Amann M, Aughey R, Billaut F, Bishop DJ, Bourdon P, Buchheit H, Chapman R, D'Hooghe M, Garvican-Lewis LA, Gore CJ, Millet GP, Roach GD, Sargent C, Saunders PU, Schmidt W, and Schumacher, YO. 2013. Position statement--altitude training for improving team-sport players' performance: current knowledge and unresolved issues. British Journal of Sports Medicine 47:i8-i16.
4. Girard O, Brocherie F, and Bishop DJ. 2015. Sprint performance under heat stress: a review. Scandinavian Journal of Medicine & Science in Sports 25:79-89.
5. Girard O, Brocherie F, Morin JB, and Millet GP. 2016. Running mechanical alterations during repeated treadmill sprints in hot versus hypoxic environments. A pilot study. Journal of Sports Sciences 16:1-9.

*Thursday 8th September*
*Chairperson: Glen Deakin*
*Room 1 – Raffles*

## Preliminary evidence of a heat hangover, a new heat illness classification for occupational settings?

**Matt Brearley**[1,2,3]
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The relationship between environmental heat and morbidity and mortality is well described and clearly discernable through prolonged periods of abnormally hot weather, otherwise known as heatwaves. The eight day Sydney (Australia) heatwave of 2011 resulted in an excess of ~4000 emergency department visits, ~1500 ambulance call outs and 132 deaths[1]. Yet, only 8% of both the excess emergency department visits and ambulance callouts were attributed to heat related illnesses (HRI) and/or dehydration, as health statistics indicate that heatwaves predominantly impact those with diseases of the nervous, circulatory and respiratory systems, and those with underlying mental and behavioural disorders[2]. In addition to chronic disease sufferers, the cohorts most susceptible to elevated ambient temperatures are persons with impaired capacity for thermoregulation, inclusive of infants and the elderly, and groups with high metabolic heat production such as workers in labour intensive industries. The latter group presents a unique thermoregulatory challenge during heatwaves and hot weather in general that is exacerbated by the addition of mandatory personal protective clothing, effectively insulating the skins surface and curbing body heat dissipation. Despite the apparent heat related risks to the 1.8 million workers employed in the Australian agriculture, mining, utilities and construction industries[3], heat as a workplace hazard is poorly characterised[4].

While worker heat illness is approximately 4–7 times more likely during heatwave periods[5], and worker injury claims are positively related to ambient temperature[6], on average, less than 50 workers compensation claims are awarded in Australia per year for exposure to environmental heat[7] (Safework). Such a low frequency appears reflective of underreporting that may be associated with how symptoms manifest and/or how HRIs are classified. The often-cited spectrum of HRIs (listed in order of seriousness) are heat stroke, heat exhaustion, heat syncope, heat cramp and heat rash. Of these, heat stroke is the sole illness with clinical diagnostic criteria inclusive of substantially elevated core temperature, prompting Noakes[8] assertion that the remaining conditions be removed from heat illness lexicon. Further complicating the classification of HRI is the lack of standardised definitions. For example, while heat exhaustion is the most common HRI observed from hospital presentations[9], definitions range from a combination of generalized weakness, headache, fatigue, nausea and hyperventilation, to a state of extreme physical and mental fatigue related to heat. The demarcation of HRIs is an important issue, as precisely identifying heat related symptoms in occupational settings would facilitate targeted measures to mitigate risk.

In an effort to determine the symptoms of chronically heat acclimatised workers and their impact upon work and social factors, a pilot investigation identified headaches, nausea, loss of appetite and vomiting as a common result of working in hot conditions. While similar symptoms have been reported in other occupational settings exposed to heat[10], the heat acclimatised workers indicated that such symptoms would not prompt them to seek medical treatment, as they were generally developed towards the end of, or following the work shift. Thus a latency period between exposure and symptom onset was identified, potentially impacting classification of symptoms. Overall, the self-reported symptoms and manner of manifestation mimic those of an alcoholic hangover. In selected workplaces where the term ‘heat hangover’ has been used to relate the self-reported symptoms to workers during heat education curriculum, it has gained wide acceptance. While the workplace consequences of heat hangovers remain to be described, the impact of heat related symptoms on vigilance, concentration, decision making and execution of physical skills are all worthy of attention. Such work may explain the prevalence of workplace accidents in the hottest months of the year[11].

**References**

1. Schaffer A, Muscatello D, Broome R, Corbett S, and Smith W. 2012. Emergency department visits, ambulance calls, and mortality associated with an exceptional heat wave in Sydney, Australia, 2011: a time-series analysis. Environmental Health 11(1):3.
2. Khalaj B, Lloyd G, Sheppeard V, and Dear K. (2010). The health impacts of heat waves in five regions of New South Wales, Australia: a case-only analysis. International Archives of Occupational and Environmental Health 83(7):833-42.

3. Australian Bureau of Statistics. 2015. Australian Industry, 8155.0
4. Gubernot DM, Anderson GB, and Hunting KL. 2014. The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. International Journal of Biometeorology 58(8):1779-88.
5. Xiang J, Hansen A, Pisaniello D, and Bi P. 2015. Extreme heat and occupational heat illnesses in South Australia, 2001-2010. Occupational and Environmental Medicine 72(8):580-6.
6. Xiang J, Bi P, Pisaniello D, and Hansen A. 2014. The impact of heatwaves on workers' health and safety in Adelaide, South Australia. Environmental Research 133:90-5.
7. SafeWork Australia. 2011. Occupational Health and Safety Statistics Report-Number of Cases 2011.
8. Noakes TD. 2008. A modern classification of the exercise-related heat illnesses. Journal of Science and Medicine in Sport. 11(1):33-9.
9. Sanchez CA, Thomas KE, Malilay J, and Annest JL. 2010. Nonfatal natural and environmental injuries treated in emergency departments, United States, 2001-2004. Family and Community Health 33(1):3-10.
10. Hunt AP, Parker AW, and Stewart IB. 2014. Heat strain and hydration status of surface mine blast crew workers. Journal of Occupational and Environmental Medicine 56(4):409-14.
11. Nag PK, and Nag A. 2010. Shiftwork in the hot environment. Journal of Human Ergology 30(1-2):161-6.

*Thursday 8th September*
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## The influence of aerobic training on maximum skin wettedness and its effects during uncompensable heat stress

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### Introduction
Despite anecdotal evidence[1–3], no study has systematically quantified how maximum skin wettedness ($\omega_{max}$) is altered by aerobic training compared to following heat acclimation (HA).

### Methods
Five individuals (1 female) participated in a 10-week aerobic training regime followed by a 9-day heat acclimation (HA) protocol. Participants completed on separate days, i) a treadmill humidity ramp protocol trial to assess $\omega_{max}$[4,5]; and ii) a 60-min treadmill march (500 W of heat production) in an uncompensable (UC) environment: 38°C, 60% RH, on three separate occasions: pre-training (PRE-T), post-training (POST-T), and post-heat acclimation (POST-HA); The change in rectal ($\Delta T_{re}$) and mean body temperature ($\Delta T_b$), and mean skin temperature ($T_{sk}$) were recorded. Whole body sweat loss (WBSL) was calculated as the change in nude body mass. A two-way mixed model ANOVA (repeated factor: time; non-repeated factor: training/acclimation status) was used to compare $\Delta T_{re}$, $\Delta T_b$, and $T_{sk}$. A one-way ANOVA (non-repeated factor: training/acclimation status) was used to compare WBSL and $\omega_{max}$.

### Results
Aerobic training increased aerobic capacity by ~16% (PRE-T: 39.0±5.0 ml/kg/min; POST-T: 45.5±3.7 ml/kg/min, $P$=0.01). In the ramp trial, $\omega_{max}$ was lower PRE-T (0.74±0.08) compared to POST-T (0.90±0.11, $P$=0.01) and POST-HA (1.00±0.00, $P$=0.001), and POST-T tended to be lower than POST-HA ($P$=0.07).

In the UC trial, $\Delta T_{re}$ was greater PRE-T (1.17±0.18°C) compared to POST-T (0.97±0.16°C, $P$<0.001) and POST-HA (0.92±0.3°C, $P$<0.001). POST-HA $T_{sk}$ was lower after 60-min (37.1±0.5°C) compared to POST-T (37.5±0.4°C, P=0.001) and PRE-T (38.0±0.4°C, $P$<0.001). Likewise, POST-HA $\Delta T_b$ was lower after 60-min (0.7±0.2°C) compared to POST-T (0.8±0.2°C, $P$=0.05) and PRE-T (1.0±0.2°C, $P$=0.006). WBSL was significantly greater POST-HA (947±145 g) compared to POST-T (850±149 g; $P$=0.05) and PRE-T (781±204 g, $P$=0.001).

### Conclusion
Preliminary results indicate aerobic training and HA independently increase $\omega_{max}$, and the concomitant reduction in thermal strain during UC seems greater POST-T compared to PRE-T than POST-HA compared to POST-T.

### References
1. Alber-Wallerström B. Efficiency of sweat evaporation in unacclimatized man working in a hot humid environment. Eur J Appl Physiol. 1985;54(5):480-487.
2. Havenith G, Middendorp H van. The relative influence of physical fitness, acclimatization state, anthropometric measures and gender on individual reactions to heat stress. Eur J Appl Physiol. 1990;61(5-6):419-427.
3. Mora-Rodriguez R, Coso JD, Hamouti N, Estevez E, Ortega JF. Aerobically trained individuals have greater increases in rectal temperature than untrained ones during exercise in the heat at similar relative intensities. Eur J Appl Physiol. 2010;109(5):973-981.
4. Kenney WL, Zeman MJ. Psychrometric limits and critical evaporative coefficients for unacclimated men and women. J Appl Physiol. 2002;92(6):2256-2263.
5. Dougherty KA, Chow M, Kenney WL. Critical environmental limits for exercising heat-acclimated lean and obese boys. Eur J Appl Physiol. 2009;108(4):779-789.

# Short time trial performance of trained and untrained men in two environmental conditions.

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## Introduction

It has been shown that pacing strategies during time trials are altered in different environmental conditions and by acclimatization[1]. The purpose of this study was to compare the pacing strategies of trained (TR) versus untrained (UT) men in normal and warm, humid environments.

## Methods

17 males (8, TR; 9, UT) aged 25.5 ± 6.1 yr versus UT with a greater body fat of 8.7% ($P < 0.05$) participated. TR exercised at least 3 d/week for 6 mo leading up to the study whereas, UT were sedentary. Before and after familiarization, maximal voluntary contraction (MVC) and voluntary activation (%VA) were measured. Each group (TR & UT) randomly completed 2 x 25 min cycle time trials (TT) in either 21.8 °C, 51% *rh* (NORM) or warm humid (32.2 °C, 68% *rh*) conditions separated by 7 – 10 d. TT were interspersed with 5 x 30 s maximal effort sprints each 4.5 min.

## Results

Distance was similar between TR (12.5 ± 1.4 km) and UT (11.5 ± 0.9 km) in the NORM but TR cycled further (12.2 ± 1.3 vs 10.9 ± 1.5 km; $P < 0.05$) in the heat with higher power output (PO) ~ 17.9 W/kg, ($P < 0.05$). TR achieved higher PO during sprints in both conditions. Core temperatures were similar after the TT between groups in NORM (~ 38.2 °C) and warm (~ 38.4 °C) conditions. VA was 10.4% lower ($P < 0.05$) in UT compared to TR following the TT in NORM.

## Conclusions

The better performance in the heat by TR can be attributed to their improved physiological capacity from training. This also provided a different pacing strategy during the sprint sections in the heat, allowing them to maintain a higher PO. The fact that TR maintained higher %VA also indicates an attenuated central drive.

## References

1. Racinais S, Périard JD, Karlsen A, Nybo L. Effect of heat and heat acclimatization on cycling time trial performance and pacing. Med Sci Sports Exerc. 2015;47(3):601–6.

# Dose-response effects of ambient temperature on resistance training outcomes in elite weightlifters

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**Introduction**
Augmenting power output and hormone responses during exercise are known to optimise training adaptation[1-3]. This study aimed to examine the effects of ambient temperature during resistance training on the performance and hormonal responses of elite weightlifters.

**Methods**
Nine elite weightlifters (age 26.3±4.4 y; height 172.3±15.2 cm; body mass 92.9±28.7 kg) completed three training sessions involving four sets of three squats at 90% one-repetition maximum. Squats were performed in an environmental chamber set at 24°C, 30°C or 35°C, with the relative humidity fixed at 55%. Power was measured via linear transducer, and salivary cortisol and testosterone were taken pre- and post-squats. The data were compared using repeated measures analysis of variance. Regression analysis was completed to examine the dose-response relationship between ambient temperature and each of the outcome measures.

**Results**
Peak power was significantly greater for 30°C (2435±814W) and 35°C (2400±895W) compared to 24°C (2266±882 W; $p<0.05$). Regression analysis predicts maximal peak power at 31.5±4.2°C with 10.1±10.9% greater peak power than 24°C Post-squats salivary cortisol concentration was significantly greater for 35°C (29.1±11.5 $nmol.L^{-1}$) compared to 24°C (21.4±4.6 $nmol.L^{-1}$, $p<0.01$), but not significantly greater for 30°C (23.5±13.2 $nmol.L^{-1}$; $p>0.05$). Post-squats salivary testosterone concentration was significantly greater for 35°C (1.28±0.27 $nmol.L^{-1}$) compared to 24°C (1.16±0.24 $nmol.L^{-1}$; $p<0.05$), but not significantly greater for 30°C (1.20±0.38 $nmol.L^{-1}$; $p>0.05$).

**Conclusion**
A relationship between temperature and training outcomes seems apparent, with a quadratic polynomial regression predicting that 31.5°C will produce maximal peak power output 10% greater than at 24°C. This temperature is aligned with the transition from nonsignificant to significant effects on salivary cortisol and testosterone concentrations.

**References**
1. Beaven, C. M., Cook, C. J., & Gill, N. D. (2008). Significant strength gains observed in rugby players after specific resistance exercise protocols based on individual salivary testosterone responses. The Journal of Strength & Conditioning Research, 22(2), 419-425.
2. Pareja-Blanco, F., Rodríguez-Rosell, D., Sánchez-Medina, L., Sanchis-Moysi, J., Dorado, C., Mora-Custodio, R., ... & González-Badillo, J. J. (2016). Effects of velocity loss during resistance training on athletic performance, strength gains and muscle adaptations. Scandinavian Journal of Medicine & Science in Sports.
3. West, D. W., & Phillips, S. M. (2012). Associations of exercise-induced hormone profiles and gains in strength and hypertrophy in a large cohort after weight training. European Journal of Applied Physiology, 112(7), 2693-2702.

# Effect of short-term heat training on intermittent running performance in a temperate environment in team sport players

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**Introduction**
Team sports players are constantly looking for ways to gain a competitive advantage come game time. Short-term heat training may offer performance benefits in a temperate environment[2]. However, the transfer between heat training to performance under temperate conditions is not well understood[1]. The aim of the study was to quantify changes in Yo-Yo IRT1 test performance in a temperate environment following a short-term heat training intervention.

**Methods**
A crossover design involved ten club-level Australian Rules footballers completing one 14 day training block in HEAT (35°C, 50% RH) and one in TEMP (18°C, 50% RH) conditions, each comprising of 6 x 60 min training sessions. Before and after each training block, participants completed the Yo-Yo test in temperate an environment (18-22°C). Heart rate was monitored throughout the Yo-Yo test and RPE and thermal sensation (TS) collected 5 min after the test. Data was log-transformed to assess standardised mean changes and differences with precision of estimation indicated using 90% confidence limits.

**Results**
Distance covered during the Yo-Yo test increased by 9 ± 17% (150 ± 270 m; mean ± 90% confidence limits) and 12 ± 9% (230 ± 160 m) in HEAT and TEMP with an unclear difference between conditions (ES 0.24 ± 0.64). Irrespective of environmental conditions, a training effect was indicated by a large 470 m increase (ES 1.31 ± 0.30) in distance covered between the first and final Yo-Yo test of the study. Changes in $HR_{max}$ (ES -0.08 ± 0.35), RPE (ES = 0.37 ± 0.79) and TS (ES = 1.03 ± 1.58) after the Yo-Yo test were unclear.

**Conclusion**
Six heat-training sessions within a 14 period failed to evoke physiological responses indicative of classical thermal adaptation. Moderately-fit football players appear to benefit more from additional fitness training than short-term heat training.

**References**
1. Corbett J, Neal RA, Lunt HC, Tipton MJ. Adaptation to heat and exercise performance under cooler conditions: a new hot topic. Sports Medicine. 2014;44(10):1323-31.
2. Lorenzo S, Halliwill JR, Sawka MN, Minson CT. Heat acclimation improves exercise performance. Journal of Applied Physiology. 2010;109(4):1140-7.

# Dissociation between physiological and perceptual markers in short-term heat training: a case study

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**Introduction**
Heat acclimation is employed by many team sports to induce extra physiological adaptations for enhancing performance in both hot and temperate conditions[1,2]. However, changes in physiological and perceptual responses to short-term heat training may differ in magnitude. The aim of this case study was to compare the relative changes in classical physiological and perceptual markers after short-term heat training.

**Methods**
A male AFL player (age: 21 y; body mass: 81.7 kg; height: 177.5cm) completed a 'HEAT' training block in 35° C, 60% humidity involving 6 x 1 h training sessions followed by a 1 month washout period. The same training but in temperate (TEMP) conditions (18-22°C, 50% humidity) was then performed. Each 1 h session involved 5 x 8 min moderate intensity exercise (running and cycling). A treadmill heat stress test (HST) before and after each training block involved 4 submaximal stages where heart rate (HR) and rating of perceived exertion (RPE) were measured. Data was log-transformed to assess standardised mean changes with precision of estimation indicated using 90% confidence limits. Descriptive data is represented by mean ± standard deviation.

**Results**
There was a substantially larger reduction in HR (5 ± 3 bpm, ES 1.45, ±0.74; mean, ±90% confidence limits) in the HST after the HEAT compared with TEMP training. HR during the heat training session was reduced from 189 ± 5 bpm (mean ± SD) in the first session to 160 ± 16 bpm in the last session. However, the difference in the change in the mean RPE score between conditions was unclear (ES -1.09, ±2.15).

**Conclusion**
The large reduction in heart rate after heat training than training in temperate conditions was not reflected by changes in perceptual markers. Monitoring heat training adaptation should involve both perceptual and physiological markers.

**References**
1. Chalmers S, Esterman A, Eston R, Bowering KJ, Norton, K. Short-Term Heat Acclimation Training Improves Physical Performance: A Systematic Review, and Exploration of Physiological Adaptations and Application for Team Sports Short-Term Heat Acclimation Training Improves Physical Performance: A Systematic Review, and Exploration of Physiological Adaptations and Application for Team Sports. Sports Medicine. 2014; 44 (7):971-1018.
2. Lorenzo S, Halliwill JR, Sawka MN, Minson CT. Heat acclimation improves exercise performance. Journal of Applied Physiology. 2010;109(4):1140-7.

*Thursday 8th September*
*Chairperson: Rod Pope*
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## Immediate post-exercise cooling following heat acclimation training improves cycling performance

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**Introduction**
While heat acclimation (HA) training is an effective means to promote rapid physiological and performance adaptations in a short-period of time[2], these interventions often increase fatigue[3]. The purpose of this study was to quantify the effect of immediate whole-body cooling following HA training to optimise recovery and performance across an intense short-duration (7 day) protocol.

**Methods**
Twenty four moderately trained males ( age 23.8 ± 4.4 years, stature 1.76 ± 0.1 m, body mass 76.5 ± 8.7 kg, $VO_2$ max 46.4 ± 5.3 $ml.kg.min^{-1}$; mean ± SD) were allocated to either Cool (n=12) or Passive (n=12) training groups and undertook four daily sessions of HA training. Before and after HA training participants undertook a time-to-exhaustion (TTE) test in thermo-neutral conditions (20 °C, 50% relative humidity) and a heat stress test (HST) that included a 5 km time trial in hot conditions (38°C, 60% RH) on a cycle ergometer[1]. Participants in Cool received a 20 min post-exercise cooling intervention comprising whole-body fanning (~3.6 $m.s^{-1}$) and ingestion of a 500 ml ice-slushy immediately after each training session.

**Results**
Cool had a 30%, ±37% (mean, ±90% confidence limits, p=0.03) moderately greater improvement in TTE performance in thermo-neutral conditions and a small 4.0%, +4.7% (p=0.04) improvement in 5km TT performance in hot conditions compared to Passive. Cool also reported lower levels of fatigue than Passive after the HA training (6.5 ± 0.5 vs 8.5 ± 1.0 RPE units, p= 0.01).

**Conclusion**
Immediate post-session cooling after short-term heat acclimation training improves cycling performance in hot and thermo-neutral conditions and reduces sensations of fatigue. Mixed cooling methods utilising whole-body fanning and ice-slushies are a simple and efficient recovery intervention.

**References**
1. Guy JH, Pyne DB, Deakin G, Miller CM, and Edwards AM. 2016. Acclimation training improves endurance cycling performance in the heat without inducing endotoxemia. Frontiers in Physiology 7:318.
2. Tyler CJ, Reeve T, Hodges GJ, and Cheung SS. 2016. The Effects of Heat Adaptation on Physiology, Perception and Exercise Performance in the Heat: A Meta-Analysis. Sports Medicine 1-26.
3. Wingfield GL, Gale R, Minett GM, Marino FE, and Skein M. 2016. The effect of high versus low intensity heat acclimation on performance and neuromuscular responses. Journal of Thermal Biology 58:50-59.

# The metabolic and cardiovascular demands of Singapore firefighting breathing apparatus proficiency test

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**Purpose**
The metabolic demands of essential generic firefighting tasks in the Singapore Civil Defence Force have not been quantified. Understanding these demands may be important in establishing minimum acceptable occupational physical fitness standards, thereby ensuring that personnel can perform critical tasks safely and effectively. This study aimed to quantify the metabolic and cardiovascular strain during firefighting Breathing Apparatus Proficiency Test.

**Methods**
Eighty (80) male trained Singapore firefighters (mean ± SD, age 29 ± 5.5y, height 1.72 ± 0.05 m, body mass 69.1 ± 8.4 kg, estimated VO2 max 42.8 ± 7.0 mL.kg-1.min-1) performed the Breathing Apparatus Proficiency Test (BAPT) with five different tasks (treadmill Station (TS), Ladder Station (LS), Cycling Station (CS), Impact Machine Station (IMS) and Maze Station (MS)) in a standard order whilst wearing a standard firefighting ensemble (loaded with 20kg of personal equipment). Heart rate, breathing frequency and oxygen uptake were measured whilst participants completed each task at the pre-determined or self-initiated pace. Repeated measures ANOVA was used to identify differences in physical demand between tasks.

**Results**
The average HR for TS, LS, CS, IMS and MS were 123.1 ± 19.38 bpm, 169.9 ± 19.01 bpm, 169.9 ± 19.01 bpm, 168.3 ± 14.92 bpm, and 181.2 ± 19.47 bpm. These values corresponds to 68.5 ± 9.85%, 92.9 ± 9.86%, 88.3 ± 9.59%, 91.8 ± 11.33% and 99.5 ± 12.94% respectively when expressed as % HRpeak values. Performing the climb test, strength test, cycle test and orientation test on the ladder, impact machine, and bicycle and maze stations elicited HR values above 80% HRpeak. The average VO2 (ml/kg/min) for TS, LS, CS, IMS and MS were 22.9 ± 5.42, 38.8 ± 9.52, 28.7 ± 7.65, 26.8 ± 7.88, and 181.2 ± 19.47 bpm. Performing the Ladder, Impact Machine, and Bicycle and Maze test stations elicited VO2 values between 60 and 85% VO2peak. Treadmill test scored the lowest VO2 values (22.9 ± 5.42 ml/kg/min). Lowest BF in TS suggests that, when compared to the other stations, the intensity of walk test protocol may be not strenuous enough to elicit recommended workload between 60 and 80 % of their VO2peak.

**Conclusions**
Core firefighting activities require substantial physical exertion with ladder climbing and load performing activities eliciting the highest physical demand. A more occupational task-related tests to be included in the Breathing Apparatus Proficiency Test. Productivity is based on efficiency of fire-fighters to be fitter and the ability to perform fire-fighting suppression tasks effectively.

Keywords: Firefighting, physiological demand, occupational task, efficiency

# Lifetime prevalence of non-melanoma and melanoma skin cancer in Australia surfers

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**Introduction**
Surfing is one of the most popular aquatic activities in Australia with an estimated 2.7 million recreational surfers [1] however, Australia has long been recognized as having the highest incidence of melanoma in the world. As a result the expected risk of skin cancer in surfers due to long periods of exposure to ultraviolet radiation is of great concern [2]. The aim of this study was to investigate the lifetime prevalence of non-melanoma skin cancers (NMSCs), (basal cell carcinoma (BCC), squamous cell carcinoma (SCC)), and melanoma skin cancers (MSCs) in Australian surfers.

**Methods**
Given the geographic distribution of surfers in Australia, we utilized an online surveillance survey to determine the lifetime prevalence of NMSCs and MSCs. The survey consisted of physiological demographics (age, Ht, mass) and surfing specific demographics (board type, surfing exposure, ultraviolet exposure and skin type). Participants were instructed to report only NMSCs and MSCs by type/location that have only been diagnosed and/or treated by either a general practitioner (GP) or dermatologist.

**Results**
A total 1,348 surfers participated, of which 184 surfers reported a skin cancer. Of skin cancers reported for the entire cohort, BCC was the most common (6.8%), followed by melanoma (1.4%) and SCC (0.6%). Relative risk was higher ($p<0.001$) in competitive versus recreational surfers (OR 1.74 (CI 1.28-2.31)). A significantly ($p<0.05$) higher number of skin cancers were reported on the face (23.5%), back (16.4%) and arms (12.4%). There were significant ($p<0.001$) trends in reported skin cancers between competitive and recreational surfers, as well as significantly ($p<0.001$) more skin cancers reported in males (14.6%) than females (9.4%).

**Conclusion**
Based upon these findings, individuals who surf are advised to regularly utilize sun protection strategies (avoid peak ultra violet radiation, rashvest, hat and sunscreen) and primary care physicians are recommended to regularly screen their patients who surf.

**References**
1. Stark A. 2013. Surfing Australia Annual Report.
2. Moehrle M. 2008. Outdoor sports and skin cancer. Clinical Dermatology 26:12-15.

## Crime in the Tropics: Is sport part of the solution, or part of the problem?

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**Introduction**
Sport is recognised as having an important positive social function with positive social returns on investment. For example, UK data show that for every £1 spent on sport, £1.91 worth of benefits are generated[1]. This includes improvements in good health and reduced risks of coronary heart disease, breast cancer, Type 2 diabetes, etc. There are also social benefits, such as reductions in crime, improved educational performance, and enhanced social capital (volunteering)[2]. However, the status of sport as a positive social force is under threat[3]. While the use of banned performance and image enhancing drugs (doping) is currently the most visible threat to the integrity of sport, other concerns such as match-fixing, violence (on and off the field), sexual assault and multiple forms of discrimination, are also emerging as potential threats[4]. Concerns over the positive and negative impact of sport are of considerable significance to many tropical communities, where sport has increasingly become one of the primary social engineering tools, used to build communities and to prevent social problems such as drug use and criminality. There is a growing body of evidence that prompts the following question: is the intended cure actually a cause of some of the problems currently experienced in North Queensland communities?

**Methods**
The study will involve surveying the attitudes and opinions of a broadly representative sample of North Queensland athletes and support personnel (coaches, doctors etc.) about the positive and negative impact of sport on a range of social and health related issues. Questions will be structured to assess both awareness and perceptions at local (Tropical NQ), state (QLD) and national (Australian) levels. Data collection is ongoing, with the paper presenting results from an initial sample of 150 participants (63% male, 37% female; mean age 26.7 years; main sports included soccer, basketball, rugby league, triathlon).

**Results**
Participants saw the problems of doping, physical violence, homophobia and racism as the most serious problems for sport in the North Queensland Region. For most problems the issue was seen as less severe in the NQ region than across the state of Queensland and across Australia. Doping was identified as the problem that had increased the most in NQ in the last five years (followed by sexual harassment). Participants were most confident that the problem of doping would be punished, with homophobia seen as the offence least likely to be punished.

**Conclusion**
The preliminary results suggest that the participants acknowledge that doping, physical violence, homophobia and racism are problems in the NQ region, but in common with general criminological trends, see the problem as a greater concern in the rest of Queensland and Australia. That is, with increasing levels of abstraction, and thus less direct personal exposure, perceived criminological threats are intensified. Overall the results show that participants believe that problem behaviours are relatively common in sport and as such any attempts to build communities through sport may actually reinforce existing problems rather than solving them. Perceptions of problems, which may in fact be wrong, may be a significant barrier to realising the social and health related potential of sport.

**References**
1. Davies, L., Taylor, P., Ramchandani, G., & Christy, E. (2016). Social Return on Investment in Sport: A participation-wide model for England. Summary Report. Retrieved from Sheffield, UK: http://www.shu.ac.uk/_assets/pdf/research/sirc/Final-SIRC-SROI-England-Web-report.pdf
2. Engelberg, T., Skinner, J., & Zakus, D. (2014). What does commitment mean to volunteers in youth sport organizations? Sport in Society, 17(1), 52-67. doi:10.1080/17430437.2013.828900
3. Moston, S., & Engelberg, T. (2014, October). The Doping Age. Australasian Science, 35, 17-19.
4. Engelberg, T., & Moston, S. (2016). Hiding in plain sight: sexual harassment in sport. In M. Barry, J. Skinner, & T. Engelberg (Eds.), Research handbook of employment relations in sport (pp. 295-309). Cheltenham, UK: Edward Elgar Press.

## Teaching physical education to ECE learners through the use of the coconut tree and the ECE Games

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An innovative, sustainable and relevant approach to teaching physical education in the three levels of education (early childhood education – ECE, primary and secondary schools) in the Solomon Islands was developed and used in 2012, 2013 and 2015. These ECE Games were created with the use of local materials to demonstrate to ECE and Primary schools throughout the country, that Physical Education could be taught with the use of local materials creatively in a sustainable manner.

The ECE Games ignited and transformed the idea of using the coconut tree for the teaching of physical education in early childhood classes. These games have set the foundation for school teachers to think outside the box and start using local materials. The coconut tree played a significant part in laying the foundation that stimulated the teachers' minds to be innovative, creative and integrative in the planning and teaching of physical education.

Since the inception of the ECE Games, ECE teachers have transformed and demonstrated significant changes in their approach and delivery of physical education in their schools. This study explored the following questions: Why is the coconut tree overlooked in the teaching of physical education? Can indigenous knowledge be used in the teaching and delivery of physical education? Why are these approaches not used and how can then be used? Examples of the coconut tree and how it is used through the ECE Games and an appreciation of coconut tree's use for the teaching physical education will be explored.

Keywords: physical education, innovative, teacher resources, curriculum, Solomon Islands

# Officiating role influences the physical match activity profiles of rugby league touch judges and referees

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**Introduction**
To date, the movement profiles of rugby league match officials have a scarcity of notational research. This study investigated the effect of officiating role on the physical activity profiles of rugby league match officials during game-play. Match officials were included from both the Queensland Rugby League Intrust Super Cup and the National Youth Competition.

**Methods**
Physical performance indicators were collated from 23 match officials, resulting in 78 observations. Match officials were categorised into two groups; referees and touch judges. Microtechnology facilitated the quantification of total distance (m), relative distance ($m \cdot min^{-1}$), maximum velocity ($m \cdot s^{-1}$), percentage of high intensity running distance (% total >3.01 $m \cdot s^{-1}$), walking distance (<1 $m \cdot s^{-1}$), jogging distance (1.01 – 3 $m \cdot s^{-1}$), fast jogging distance (3.01 - 5 $m \cdot s^{-1}$), and sprinting distance (>5$m \cdot s^{-1}$).

**Results**
Multivariate analysis modelled the main effect of officiating role with follow up univariate analyses identifying significant differences. A significant effect was noted ($V = 750$; $F(8, 66) = 24.71$; $p < 0.05$) with referees covering a greater total distance (7767 ± 585 vs. 7022 ± 759 m), relative distance (90 ± 6 vs. 82 ± 8 $m \cdot min^{-1}$), jogging distance (3772 ± 752 vs. 3110 ± 553 m), and fast jogging distance (2565 ± 631 vs 1816 ± 440 m) compared to touch judges. Touch judges covered greater distances while sprinting (1012 ± 385 vs. 654 ± 241 m).

**Conclusion**
Rugby league match officials of different adjudicative roles (middle referee and touch judge) do indeed generate distinctive physical activity profiles during game-play. However, unlike sports such as soccer, the match officials from rugby league sub-elite competitions may undertake either role dependent upon the selection roster, which is determined on a weekly basis. Therefore, it is suggested that training programs for match officials be designed to consider both match official roles to equally optimise the performance required of each role during game-play.

# Synchronous league-wide evolution of game-play in the Australian Football League from 2001-2015: Implications for performance analysis in team sports

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**Introduction**
Since its origination in the mid 1800's, Australian football (AF) has evolved drastically. The primary aim of this study was to model the evolution of modern (from the 2001-2015 seasons) game-play in the Australian Football League (AFL) manifested via team performance indicator characteristics. A secondary aim was to introduce novel data visualization techniques to the sport sciences.

**Methods**
Mean values for 18 performance indicators were collated for every AFL team over 15-seasons. There were a total of 16 teams in the AFL from 2001 to 2010, 17 teams in 2011, and 18 teams from 2012 to 2015, resulting in a total of 249 observations. A multivariate analysis was used to uncover trends in the dynamics of the team performance indicators. Multivariate methods were chosen as they enable mapping of collective (team) game-styles rather than analysing individual indicators. Further, this method allowed the capturing of temporal trends, simultaneously accounting for all the variables in the dataset.

**Results**
Between the 2005 and 2010 seasons were characterised by large growth in the counts of handballs, disposals, uncontested possessions, clangers, marks, and tackles. Contrastingly, the percentage of effective disposals declined rapidly during this period. The number of inside 50 m counts remained relatively stable throughout the 15-season period. The ordination plot of league-wide performance indicator characteristics illustrated a distinct cluster from the 2001 to 2004 seasons, an abrupt shift in team performance indicator characteristics from the 2005 to 2009 seasons, and an emergent (re)stabilisation from the 2010 to 2015 seasons.

**Conclusions**
The results of this study demonstrate the synchronous league-wide evolution of game-play in the AFL from the 2001 to 2015 seasons. Amongst other constituents, this dynamic evolution is likely to reflect the introduction of modernised coaching styles, frequent rule changes to modify the style of game-play and changing perceptions of rule interpretations.

# Identifying the physical fitness, anthropometric and athletic movement qualities discriminant of developmental level in elite junior Australian football

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**Introduction**
The identification and subsequent development of talent is critical in the overall attainment of sporting excellence. Acknowledging this, the Australian Football League (AFL) has establishment elite talent development programmes, referred to as State Academies. These academies consist of two critical developmental stages, the under 16 (U16) and U18 levels. This study aimed to identify the physical fitness, anthropometric and athletic movement qualities discriminant of developmental level in elite junior Australian football (AF).

**Methods**
From a total of 77 players, two groups were defined according to their developmental level; U16 (n = 40, 15.6 to 15.9 *y*), and U18 (n = 37, 17.1 to 17.9 *y*). Players performed a test battery consisting of seven physical fitness assessments, two anthropometric measurements, and a fundamental athletic movement assessment. A multivariate analysis of variance tested the main effect of developmental level (two levels: U16, U18) on the assessment criterions, whilst binary logistic regression models and receiver operating characteristic (ROC) curves were built to identify the qualities most discriminant of developmental level.

**Results**
A significant effect of developmental level was evident on nine of the assessments ($d$ = 0.27 – 0.88; $P$ <0.05). However, it was a combination of body mass, dynamic vertical jump height (non-dominant leg), repeat sprint time and score on the 20 m multistage fitness test that provided the greatest association with developmental level (AICc = 80.84). The ROC curve was maximised with a combined score of 180.7, successfully discriminating 89% and 60% of the U18 and U16 players, respectively (area under the curve = 79.3%).

**Conclusions**
These results indicate that there are distinctive physical fitness and anthropometric qualities discriminant of developmental level within the junior AF talent pathway. Coaches should consider these differences when designing training interventions at the U16 level to assist with the development of prospective U18 AF players.

## The Repeated bout effect of strength training across three bouts

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**Introduction**
Recently, Doma and colleagues[1] showed no repeated bout effect (RBE) on running performance across two identical lower body strength training (ST) bouts. Subsequently, this study examined whether an additional ST bout (i.e. three ST bouts) would provide the protection needed to improve running time-trial performance (RTP).

**Methods**
Twelve resistance-untrained men completed three bouts of lower body ST at six-repetition maximum (squats, leg press, leg extension and leg curls). Running time-trial performance (RTP) was assessed 24 and 48 hours post whilst creatine kinase (CK), delayed-onset of muscle soreness (DOMS) and vertical jump (VJ) were collected immediately prior, post, 24 and 48 hours post each ST bout.

**Results**
Values of CK and DOMS following the first ST bout was significantly greater than the second and third ST bouts ($p < 0.05$), although no differences were found between the second to the third ST bouts ($p > 0.05$). Conversely, VJ was significantly following the second and third ST bout compared to the first ST bout ($p < 0.05$), although no differences were found between the second and third ST bout ($p > 0.05$). No differences were found in RTP between the first and second ST bouts ($p > 0.05$) although RTP following the third ST bout was significantly greater than the second ST bout ($p < 0.05$).

**Discussion**
From a concurrent training standpoint, maximal running sessions could be undertaken following the third bout of ST, although particular caution should be taken following the first two ST bouts.

**References**
1. Doma, K., Schumann, M., Sinclair, W. H., Leicht, A. S., Deakin, G. B., & Hakkinen, K. (2015). The repeated bout effect of typical lower body strength training sessions on sub-maximal running performance and hormonal response. European Journal of Applied Physiology, 115(8), 1789-1799.

## Team performance indicators can explain success for men's basketball at the Olympics

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### Introduction

Basketball is a highly intermittent, team sport with the key physical/physiological characteristics of basketball athletes reported previously. These characteristics contribute to individual performance but the combination of all individual performances in a coherent and collective direction ultimately results in team success. This study aimed to identify the key team performance indicators most explanatory of success in men's basketball at the Olympic Games to assist coaches with training interventions and match strategies.

### Methods

Twelve performance indicators were collated from all men's teams and matches during the basketball tournament of the 2004-2012 Olympic Games (n=118) resulting in 236 observations. A recursively partitioned conditional interference (CI) tree was grown, with the 12 performance indicators coded as the explanatory variables, while the match outcome (win/loss) was coded as the binary response variable.

### Results

Of the 12 performance indicators, five were retained within the CI tree; these being 'field goal percentage', 'steals', 'defensive rebounds', 'fouls against', and 'assists' ($P<0.05$). This resulted in the growth of seven terminal nodes with the distinctive combination of 'field goal percentage', 'steals' and 'defensive rebounds' associated with 84.2% of all match wins. The confusion matrix indicated that the CI tree successfully detected 100 of the 118 a priori classified losses (84.7%) and 94 of the 118 a priori classified wins (79.7%).

### Conclusion

This study identified unique combinations of team performance indicators from which coaches can develop match-plans oriented around increasing their team's probability of winning basketball matches at the Olympic Games.

*Thursday 8th September*
*Chairperson: Matt Brearley*
*Room 2 –Kingston*

## Assessing hydration status in occupational athletes: Challenges faces and lesson learnt

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**Introduction**
Human hydration assessment plays a major role in the prevention and appropriate treatment of heat strain in occupational, military, sports and clinical settings. The associated cost of heat strain is difficult to categorise as in many occupations, only extreme forms of heat illness are recorded to satisfy the requirement of current industrial legislation. Regardless work-place injuries and illness attributed to heat, radiation or electricity, within Australia in 2012-13, were estimated at $1.4 billion[8]. While a recent survey across a representative sample of Australians estimated the annual cost of heat strain, due to lost productivity, to be $728 per person, or a national burden of $6.9 billion per year[12].

**Assessing Hydration**
Current best-practice human hydration assessments include isotope dilution to estimate total body water, osmolality of blood, saliva, or urine; specific gravity or colour of urine; and changes in body mass compared to a baseline collected over several days[1,2]. These procedures are either expensive, invasive, require clinical laboratory equipment, rely on a non-dehydrated baseline criterion or on body fluids that are compromised in a dehydrated individual. Reviews of hydration assessment techniques have highlighted the need to develop field indices that are suitable for the evaluation of large groups of people, involved in athletic or challenging occupational situations, where dynamic (involving a baseline criterion) measurements are not necessary[1].

Urine colour is extensively promoted within industry as a self-management procedure and has shown excellent sensitivity and specificity in its assessment of hydration status[2], however it is not without its limitations. Vitamin supplementation has long been anecdotally thought to invalidate the technique, but recent evidence indicates the contrary[7]. The technique also requires the production of a urine sample, a capability that becomes compromised in a dehydrated individual. The comparison of acute or spot measurements of urine colour have also been criticised when compared with first morning voids[3], as these spot measurements can be invalidated by the consumption of large volumes of hypotonic fluids producing low concentration/light coloured urine in dehydrated individuals[5]. Despite these limitations the technique's minimal financial cost, simplicity of measurement and high degree of accuracy using a first morning void collection, has driven its uptake and extensive usage.

**Occupational Challenges**
However being hydrated first thing in the morning or on arrival at work, while beneficial, does not ensure that the workers do not become dehydrated across the course of their shift. Consider the fire fighter who emerges initially from a fire before re-entering or a bomb technician/tactical police officer who have undertaken a primary search of a building before further extending their search. Hydration assessment techniques for these high heat stress scenarios that are able to provide dynamic assessments as workers intermittently return, that also importantly do not require removal of personal protective clothing, are critical to ensuring the worker re-enters the scenario in a non-compromised condition.

Recently the eye has been identified as having the potential to provide a valid hydration assessment, where the use of other procedures is limited[9,10]. The relationship between ocular fluids (tear and aqueous humour), blood pressure and plasma osmolality has provided a case for tear fluid osmolarity[4], tear break-up time[11], and intraocular pressure[6] as potential non-invasive measures of hydration status.
This presentation will review the potential of ocular measures and other novel techniques to assess hydration status in the occupational setting.

**References**
1. Armstrong L (2007). Assessing hydration status: the elusive gold standard. Journal of the American College of Nutrition 26(5 Suppl): 575S-584S.
2. Cheuvront S, Ely B, Kenefick R, Sawka M. (2010). Biological variation and diagnostic accuracy of dehydration assessment markers. American Journal of Clinical Nutrition 92(3): 565-573.

3. Cheuvront S and R Kenefick (2014). Dehydration: physiology, assessment, and performance effects. Comprehensive Physiology 4(1): 257-285.
4. Fortes MB, Diment BC, Di Felice U, Gunn AE, Kendall JL, Esmaeelpour M, Walsh NP (2011). Tear fluid osmolarity as a potential marker of hydration status. Medicine and Science in Sports and Exercise 43:1590-7.
5. Gowans EM, Fraser CG. (1987). Despite correlation, random spot and 24-h urine specimens are not interchangeable. Clinical Chemistry 33:1080-1.
6. Hunt A, B Feigl, I Stewart (2012). The intraocular pressure response to dehydration: a pilot study. European Journal of Applied Physiology 112(5): 1963-1966.
7. Kenefick RW, Heavens KR, Dennis WE, Caruso EM, Guerriere KI, Charkoudian N, Cheuvront SN. (2015). Quantification of chromatographic effects of vitamin B supplementation in urine and implications for hydration assessment. Journal of Applied Physiology 119:110-5.
8. Safe Work Australia (2015). The cost of work-related injury and illness for Australian employers, workers and the community, 2012-13.
9. Sherwin JC, Kokavec J, Thornton SN. (2015). Hydration, fluid regulation and the eye: in health and disease. Clinical and Experimental Ophthalmology, 1-16.
10. Sollanek KJ, Kenefick RW, Walsh NP, Fortes MB, Esmaeelpour M, Cheuvront SN. (2012). Assessment of thermal dehydration using the human eye: what is the potential? Journal of Thermal Biology 37:111-7.
11. Sweeney DF, Millar TJ, Raju SR. (2013). Tear film stability: a review. Experimental Eye Research 08: 117.
12. Zander KK, Botzen WJW, Oppermann E, Kjellstrom T, Garnett ST. (2015). Heat stress causes substantial labour productivity loss in Australia. Nature Climate Change 5:647-51.

*Friday 9th September*
*Chairperson: Stephen Bird*
*Room 1 – Raffles*

## Thermoregulation in healthy and diseased/injured humans

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Introduction
Humans regulate internal temperature primarily through modulation of evaporative (sweating) and dry (skin blood flow) heat exchange. During prolonged heat exposure these responses contribute to elevations in heart rate and cardiac output, with accompanying reductions in central blood volume, plasma volume, and arterial blood pressure. Any condition/disease that alters the capacity for skin to dissipate heat will compromise thermoregulatory function, which could prove detrimental to the health of such individuals.

Presentation Content
This presentation will first address normal thermoregulatory responses and the associated cardiovascular demands of those responses. Next, the impact of a number of disease states that compromise thermoregulatory function will be discussed. Finally, the unique conditions by which severe burn injuries alter thermoregulatory function will be presented. The attendee will come away with a basic understanding of thermoregulatory control and the associated cardiovascular demands in the heat stressed human and how that control can be altered by disease and/or injured states.

*Friday 9th September*
*Chairperson: Ian Stewart*
*Room 1 – Raffles*

## Training for tactical operations in tropical environments: challenges, risks, & strategies for risk management

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**Introduction**
Tactical operators, encompassing military, law enforcement, fire and other emergency personnel, can be found in all climatic zones. These tactical operators may be deployed at short notice to tropical environments, often with limited time to acclimatise if based in more temperate zones. They are then expected to undertake arduous tactical tasks, often repeatedly and for extended periods in the tropical area. These demands combine with harsh environments, personal protective equipment (PPE), tactical loads, threats to life, and responsibility for the safety and survival of others to place immense physical and mental stresses on tactical operators. Managing the resulting risks is challenging. The aim of this presentation is to elucidate the challenges, discuss their management and identify knowledge gaps requiring further research. The presentation will draw on experienced tactical operators, research evidence, and reports of adverse events.

**Personal protective clothing, equipment and loads**
PPE (encompassing personal protective clothing and equipment) and other tactical loads are essential for protection, sustainment and effectiveness of tactical personnel. However, they are heavy, affect mobility, hasten fatigue and can compromise thermoregulation and visibility. By impeding sweat evaporation and body heat dissipation, PPE may contribute to rises in core temperature (Tc) with physical exertion and hot and/or humid conditions[1]. Heat illness, heat stroke or death can result, with field-based assessment of individual risks sometimes quite difficult in practice[2]. Operational intensity and external threats may reduce opportunities to remove PPE and cool the body and some PPE may impede access to fluid and food. The associated risks must be carefully monitored and managed in real time, with attention to tactical context, loads, clothing layers, Tc, signs and symptoms of heat illness, cooling options, nutrition, hydration, work/rest schedules and healthcare[1,2].

**Nature of tactical tasks**
Tactical personnel fulfil wide-ranging, arduous occupational roles, with roles in special tactical units often the most demanding. Terms such as 'tactical athlete' are insufficient descriptors, since athletes are not generally responsible for the safety and survival of others, can generally self-determine levels of participation, rarely require comparable PPE, and do not commonly have to schedule physical training regimes around unpredictable operational taskings. Tactical tasks are frequently critical or essential, not elective. Timelines, workloads and work/rest ratios may not be easily varied to suit ambient conditions in time-critical operational tasks but can generally be controlled in training contexts. Operational taskings are unpredictable. Long sedentary periods (eg transport, waiting in position) may be interspersed with multiple short bursts of intense physical activity; alternately, physical activity can be of long duration and sometimes repeated with little time between bouts to recover[3]. In tropical climates, this may limit opportunities to cool, hydrate and eat, resulting in pre-heated, dehydrated and fatigued[3] personnel re-entering tasks. Task-related stress can push heart rates to near maximum even at rest. Sleep deprivation due to deployment, tasks and tropical and tactical environments may impact cognitive function[3]. Tactical effectiveness may be impaired by all of these factors[3] and training must prepare personnel for these tasks and conditions while carefully managing safety risks[2,3].

**Nature of tactical operators**
Tactical operators typically identify as team workers who value teamwork, integrity, courage and good judgement in themselves and others[4,5]. They know and accept risks of the tactical role[5]. Fitness levels vary, and cultural norms can lead some to push beyond their limits. Injury rates tend to be high[6] due to the hazardous and unpredictable nature of tasks and environments. Tactical operators will often view hardship, like tropical heat and humidity, as a normal part

of the everyday work context or a challenge to be overcome. Perseverance is culturally valued but can give rise to serious health risks[2,5]. Training for tropical operations must consider risks to tactical personnel in this light, and most tactical training programs are now designed and risk-managed accordingly but safeguards can be challenging to implement[2,5].

**Rapid deployment, preparation and acclimatisation**
Tactical personnel are at times required to rapidly deploy from more temperate to tropical areas, for example to support local firefighting efforts, to keep the peace in areas of community unrest, for time-critical military missions, or to provide disaster relief. At other times, they will have more time to prepare for such deployments. Tactical personnel typically have little access to heat chambers for acclimation training and generally depend on regular exposure to tropical environments or short periods of acclimatisation on arrival, when deployed to tropical zones. Acclimatisation protocols are usually guided by available evidence but further research is needed to confirm the best ways to achieve and maintain acclimatisation[7], with attention to protocol feasibility, impacts of PPE and the need for some personnel to always be prepared and acclimatised for rapid deployments to tropical areas, which could occur at any time.

**Tactical environments**
Tactical environments are frequently harsh, encompassing a full range, from urban to rainforest, from sand and marshland to rocky terrain, from flatlands to mountains, and more. There is often little respite from environmental stressors such as radiant heat, UV radiation, humidity, insects, precipitation, wind, allergens, wet ground and vegetation, rocks, gradients, mud and dust. Additional threats may include hostile personnel, chemicals, smoke toxics and dangerous fauna and flora. Tropical zones can be particularly arduous, due to heat, humidity, precipitation, vegetation, insects, bacteria, fungal infections and more. PPE may protect from some of these but exacerbate others. Training must prepare personnel to operate effectively in the range of anticipated tactical environments, and must aim to do so safely.

**Nutrition and hydration**
During tactical *operations*, accessing adequate nutrition and hydration may be difficult due to operational intensity, external threats, PPE barriers and logistical challenges. In *training*, imposed nutrition restrictions may facilitate achievement of training objectives but maintenance of hydration is routinely emphasised and facilitated. Nevertheless, rates of fluid ingestion and absorption may not keep pace with sweat rates in hot and humid conditions, and this can have serious implications for the cardiovascular system, for thermoregulation and for survival[8]. Hydration may be self-limited to reduce incontinence and the need to urinate while in PPE, or to reduce load (carried water). Vomiting, diarrhoea, sweating, dehydration and over-drinking can all be life-threatening due to impacts on body fluid and electrolyte levels[8]. Risks may be heightened in tropical environments[8] and muscle glycogen utilisation rates will also be increased in hot and humid conditions[9]. This, and any deficits in nutrition and hydration, can lead to early fatigue and decrements in cognitive function[8]. Training approaches must consider and manage all of these risks.

**Hygiene, health care level and proximity, access and transport to services**
Heavy sweating, harsh and often dirty and hazardous work environments, close living arrangements, accompanying bacterial and fungal threats, insects, and limited access to cleaning facilities, sometimes for extended periods, can cause skin, gastrointestinal, respiratory, systemic and other medical problems. Hot and humid environments exacerbate this situation and may be poorly tolerated when ill[8]. Contusions, cuts, grazes and wounds are common due to uncontrollable, unpredictable and undetected hazards. Healthcare can be limited in level, proximity or access to air-conditioned vehicles or facilities and other body cooling options may also be limited, when managing heat stress and other conditions[2]. These risks must be carefully considered and managed in and through training and preparation.

**Scheduling physical training**
Targeted physical training to improve physical fitness is critical for tactical operators to increase their ability to perform physical tasks, and to facilitate acclimatisation[7]. However, scheduling physical training around operational demands can be very challenging, particularly if the unit's operational tempo is high and taskings unpredictable. Certain types of tactical training may take precedence over physical training and adequate recovery between physical training sessions may be difficult to achieve. Tropical heat and humidity can exacerbate these difficulties, further constraining opportunities to safely undertake physical training.

**Conclusion and recommendations**
This presentation has highlighted a range of challenges and risks associated with training for tactical operations, with a particular focus on tropical environments. Key to managing these challenges and risks is understanding the PPE and other loads carried by tactical personnel, the natures of tactical roles, tasks, operators and deployments, the tactical and tropical environments, and other factors that affect nutrition, hydration, thermoregulation, hygiene, healthcare, and training optimisation. A range of fairly standard recommendations for physical training to enhance tactical performance in the tropics can be made, relating to: pre-planning and logistical support; education of tactical operators and commanders; optimising loads and PPE; developing physical fitness and reducing body fat; acclimatisation[7]; ensuring proper progression and specificity of training (including consideration of PPE, operational contexts,

operational tasks and ambient conditions); monitoring ambient conditions and health; enforcing appropriate work/rest ratios and body cooling solutions[1]; facilitating and optimising hydration and nutrition[8]; managing other environmental threats to health; and practicing good field hygiene and sanitation. Further routine guidance on all of these is readily available, most with supporting evidence. More challenging are questions regarding *feasibility, acceptability, logistics* and *relative effectiveness in field settings* of risk management strategies for application to large numbers of tactical operators in the field. These questions require further research, addressing strategies such as: routinely providing access to effective body cooling, hydration and nutrition solutions; routinely and accurately monitoring individual Tc and risks of heat illness[2]; allowing team command staff the flexibility to dynamically manage PPE-related risks in real-time on the ground; and many of the other strategies discussed as standard recommendations above, which can nevertheless be challenging to implement in field settings. If the intention is to manage risks effectively, in training for service in tropical environments, then it is critical that the solutions proposed are feasible, acceptable to key stakeholders, logistically supported and the best option to use in the field. The adverse events considered in this presentation[2] are catalysts for thought in this regard.

**References**


1. Brearley M and Walker A. 2015. Water immersion for post incident cooling of firefighters; a review of practical fire ground cooling modalities. Extreme Physiology and Medicine 4:15.
2. Northern Territory Magistrates Courts. 2005. *Inquest into the death of Angus Lawrence [2005] NTMC 069.* Darwin, Northern Territory Magistrates Courts: www.nt.gov.au/justice/ntmc/judgements/documents/2005NTMC069.pdf
3. Murphy PJ. 2002. *Fatigue management during operations: a commander's guide.* Puckapunyal, Australia, Land Warfare Development Centre: www.defence.gov.au/Health/About/Docs/FatigueManagementHandbook.pdf
4. Gayton S. 2016. *The character strengths of Australian Army personnel* (PhD thesis). Sydney, University of New South Wales.
5. Standing Committee on Foreign Affairs, Defence and Trade. 2007. Chapter 7 – ADF Culture. In *Reforms to Australia's military justice system - Second progress report,* Standing Committee on Foreign Affairs, Defence and Trade eds, pp 35-42, Canberra, Parliament House.
6. Rudzki SJ and Pope R. 2006. Injury reductions seen in an infantry brigade using the Australian Defence Injury Prevention Program. Medicine & Science in Sports & Exercise 38(5): S348.
7. Tyler CJ, Reeve T, Hodges GJ and SS Cheung. 2016. The Effects of Heat Adaptation on Physiology, Perception and Exercise Performance in the Heat: A Meta-Analysis. Sports Medicine (Online First): DOI 10.1007/s40279-016-0538-5
8. Sawka MN, Burke LM, Randy Eichner, E, Maughan RJ, Montain SJ and Stachenfeld NS. 2007. American College of Sports Medicine Position Stand. Exercise and fluid replacement. Medicine and Science in Sports and Exercise 39:377-390.
9. Fernandez-Elías VE, Hamouti N, Ortega JF and Mora-Rodríguez R. 2015. Hyperthermia, but not muscle water deficit, increases glycogen use during intense exercise. Scandinavian Journal of Medicine and Science in Sports 25:126-134.

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*Chairperson: Kenji Doma*
*Room 1 – Raffles*

## Assessing and understanding thermoregulatory impairments in specific populations


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A large number of physiologists and sport scientists with an interest in human thermoregulation conduct experiments to assess time-dependent changes in internal (core) body temperature and thermoregulatory sweating. Often, the independent variable under examination cannot be assessed using a repeated-measures experimental design. For example, the influence of factors such as age, injury, disease, and sex, on human thermoregulatory responses must be evaluated using independent groups (i.e. different participants). Due to the large amount of metabolic heat released internally during muscular contractions, exercise is most often used as a model to challenge the thermoregulatory system. A seemingly simple question then arises: What exercise intensity should one use to compare the thermal responses of different groups/individuals so that any difference observed is truly due to an independent influence of the variable under examination, and not due to a systematic bias introduced by the selected exercise intensity?

Since the mid-1960s the most widespread approach has been to prescribe exercise eliciting a fixed intensity relative to an individual's aerobic capacity (i.e. $\%VO_{2max}$) due to a strongly held belief that $VO_{2max}$ is a potent physiological modulator of thermoregulatory responses. This view appears to originally arise from a classic study by Saltin & Hermansen[9] who reported similar absolute core temperatures at fixed relative intensities among participants with a wide range of aerobic capacities and thus vastly different rates of metabolic heat production. The prevailing rationale was that fitter participants who generated more metabolic heat must have dissipated heat at a greater rate in order to attain the same core temperature – a viewpoint apparently supported by the usual observation of greater sweat rates. While several studies in the following decades supported the notion that $\%VO_{2max}$ determines core temperature and sweating during exercise[2,3,5,6], none isolated the independent influence of $VO_{2max}$ from the potential confounding factors of metabolic heat production and body mass.

A more recent series of studies has demonstrated that, contrary to conventional wisdom $VO_{2max}$ does not seem to independently modify changes in core temperature or sweating independently in a compensable environment during cycle ergometry[7] or treadmill running[10]. That is, while a fitter person may sweat more during exercise at a fixed $\%VO_{2max}$, this is not due to $VO_{2max}$ per se, but due to the greater metabolic heat production arising from a greater oxygen consumption, and a greater rate of evaporation needed to achieve heat balance[4]. In participants varying greatly in body size, heat production per unit mass seems to be the main determinant of changes in core temperature, whereas heat production per unit body surface area seems to determine local sweat rate[1]. However recent evidence suggests that this latter relationship may be altered for local sweat rates measured on distal regions for individuals with very large differences in surface area-to-mass ratio[8].

For treadmill running on a flat surface, we found that differences in running economy, independently of $VO_{2max}$, have a large influence on changes in core temperature by virtue of the greater absolute oxygen consumption (and therefore heat production) required to run a particular speed[10]. During non-weight bearing exercise (i.e. cycling), exercise at a fixed external workload on a standard laboratory ergometer seems to elicit similar rates of heat production irrespective of $VO_{2max}$ and body mass[1,7].

In sum, we propose that the following methods should now be adopted to compare differences in time dependent thermoregulatory responses between population groups unmatched for body size and fitness:

1) Changes in core temperature should be assessed using a fixed heat production per unit mass (W/kg)
2) Local sweat rate should be assessed using a fixed heat production per unit body surface area ($W/m^2$)
3) Absolute whole-body sweat rates should be assessed using a fixed absolute heat production (W)

It follows that any differences in core temperature or sweating subsequently observed can then be confidently attributed to an independent influence of the between-group factor under examination.

**References**


1. Cramer MN, Jay O. 2014. Selecting the correct exercise intensity for unbiased comparisons of thermoregulatory responses between groups of different mass and surface area. Journal of Applied Physiology 116:1123-32.
2. Davies CT, Brotherhood JR, Zeidifard E. 1976. Temperature regulation during severe exercise with some observations on effects of skin wetting. Journal of Applied Physiology 41: 772–776.
3. Fritzsche, RG, Coyle EF. 2000. Cutaneous blood flow during exercise is higher in endurance-trained humans. Journal of Applied Physiology 88, 738–744.
4. Gagnon D, Jay O, Kenny GP. 2013. The evaporative requirement for heat balance determines wholebody sweat rate during exercise under conditions permitting full evaporation. Journal of Physiology (London) 591, 2925–2935.
5. Gant N, Williams C, King J, Hodge BJ. 2004. Thermoregulatory responses to exercise: relative versus absolute intensity. Journal of Sports Science 22:1083–1090.
6. Greenhaff PL. 1989. Cardiovascular fitness and thermoregulation during prolonged exercise in man. British Journal of Sports Medicine 23:109–114.
7. Jay O, Bain AR, Deren TM, Sacheli M, Cramer MN. 2011. Large differences in peak oxygen uptake do not independently alter changes in core temperature and sweating during exercise. American Journal of Physiology Regulatory Integrative and Comparative Physiology 301:R832–841.
8. Notley SR, Park J, Tagami K, Ohnishi N, Taylor NAS. 2016. Morphological dependency of cutaneous blood flow and sweating during compensable heat stress when heat-loss requirements are matched across participants. Journal of Applied Physiology 121:25–35.
9. Saltin B, Hermansen L.1966. Esophageal, rectal, and muscle temperature during exercise. Journal of Applied Physiology 21:1757–1762.
10. Smoljanić J, Morris NB, Dervis S, Jay O. 2014. Running economy, not aerobic fitness, independently alters thermoregulatory responses during treadmill running. Journal of Applied Physiology 117:1451–1459.

*Friday 9th September*
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*Room 2 – Kingston*

## Cooling interventions for exercise in the tropics: Enhancing performance, recovery and physiological adaptations

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**Introduction**

Hot and humid ambient conditions present an extremely challenging environment to undertake exercise. The ability of the body to dissipate heat to the environment is greatly reduced under such ambient conditions, as the pressure gradients necessary for the transfer of heat and evaporation of sweat are considerably decreased. Exercise undertaken in such conditions leads to the progressive increase in body temperatures and subsequently hyperthermia, leading to profound homeostatic perturbations, including increased cardiovascular, metabolic and perceptive strain [3]. While such physiological perturbations have been shown to decrease exercise performance/capacity and inhibit subsequent recovery [3,8], the longer term systemic and muscular adaptations conferred by exercising in the heat appear to be beneficial [2,12]. The following sections will briefly describe the cooling modalities and mechanisms associated with enhancing performance, recovery and muscle adaptations with regards to exercise undertaken in the heat.

**Cooling Interventions to Enhance Exercise Performance in the Heat**

The deleterious effects of hyperthermia on prolonged exercise performance are well documented in the literature [3]. The attainment or anticipation of a critically high level of body temperature has been proposed as the main factor limiting prolonged exercise in hot environments [10] and is associated with earlier volitional exhaustion during fixed intensity exercise or a decrease in work-rates during self-paced trials [10]. Subsequent research has thus focused on investigating the effects of practical modalities of lowering initial body temperature prior to exercise (i.e., precooling), or attenuate the rate of heat gain during exercise (i.e., percooling), such that the capacity for body heat storage is enhanced. Such modalities may be externally applied, such as wearing ice jackets and application of ice packs/towels, or internal in nature, including the ingestion of cold water or ice slurries, or a combination of internal and external methods [9]. These methods in general have been shown to be effective in decreasing thermal and cardiovascular strain, in line with improved endurance or prolonged intermittent exercise performance [9]. With regards to internal cooling modalities, an alternative mechanism has been recently proposed, whereby improvements in exercise performance is suggested to be due to improved thermal comfort, mediated by altered afferent feedback from thermoreceptors located in the mouth and/or gastrointestinal regions [1]. This notion is supported by recent studies demonstrating improved exercise performance (despite no differences in body temperatures) following the swilling of ice slurries or menthol solutions [1,11].

**Cooling Interventions to Enhance Recovery following Exercise in the Heat**

The use of cooling modalities, particularly in the form cold water immersion (CWI) is gaining considerable popularity among athletes to minimize fatigue and accelerate post-exercise recovery. Current CWI protocols vary considerably, but are typically performed between 10-15°C for 5-15 min in the literature [5]. Although CWI has been suggested to facilitate post-exercise recovery through multiple mechanisms, it's relevance with assisting with recovery from exercise in the heat is primarily through decreasing body temperatures, which apart from enhancing the capacity for heat storage, has been shown to alleviate hyperthermia-induced central fatigue, as well as cardiovascular strain [5]. For instance, compared with a control trial, CWI has been shown to improve the recovery of maximal voluntary contraction force, as well as voluntary activation following 60-70 min of intense intermittent exercise performed in the heat [7,8]. With regards to cardiovascular strain, CWI has been shown to attenuate the compensatory increase in heart rate, which is typically evident when rising body temperatures during exercise result in the redirection of blood flow from the active musculature to the cutaneous circulation for heat dissipation and temperature regulation [5]. The precise mechanisms by which CWI alleviate cardiovascular strain are not fully understood, but it is suggested to be due its ability to rapidly initiate cutaneous vasoconstriction and decrease core body temperature, which consequently redirects blood back into the central circulation, while limiting the need to redirect blood to the skin due to decreased thermoregulatory demand for heat dissipation [5].

**Cooling Interventions to Enhance Physiological Adaptations to Exercise**

While exercising in the heat has been well shown limit performance and prolong subsequent recovery, the systemic adaptations conferred by heat acclimation are well documented, and are likely beneficial for endurance performance in heat as well as in cooler environmental conditions [2]. Moreover, there is emerging evidence from cell culture and *in* *vivo* rodent models demonstrating enhanced cell signalling related to mitochondrial biogenesis following either passive or post-exercise heat exposure [12]. In line with these findings, there is a possibility that post-exercise CWI be utilised as a strategy to further enhance muscle oxidative adaptations to heat acclimation, in addition to its role as a recovery intervention. For instance, in a recent study, it was shown that 15 min of post-exercise CWI (10°C) resulted in increased mRNA content of peroxisome proliferator-activated receptor gamma co-activator-1 alpha (PGC-1α), a key transcriptional co-activator regulating mitochondrial biogenesis [6]. In a follow up investigation, it was demonstrated that regular post-exercise cooling of the muscles enhanced the training-induced abundance in PGC-1α, along with several mitochondrial proteins and upstream signalling kinases [4]. However, while these studies demonstrate that post-exercise CWI may enhance mitochondrial adaptations to exercise, whether it would further enhance mitochondrial adaptations following heat acclimation is putative and remains to be investigated.

**Summary**

In summary, exercise performance and capacity in heat may be enhanced by a number of precooling and/or percooling strategies targeted at increasing the capacity for body heat storage and/or manipulating thermo-sensitive afferents located in the oral and/or gastrointestinal regions. Practical cooling modalities include the use of ice jackets, application of ice packs/towels, ingestion of cold water or ice slurries, or a combination of these methods. The use of CWI is gaining considerable popularity as a recovery strategy among athletes. It is typically performed between 10-15°C for 5-15 min and the beneficial effects of CWI are generally believed to be associated with the rapid reduction in body temperature, which in turn may ameliorate fatigue associated with hyperthermia and cardiovascular strain. There is emerging evidence indicating that CWI may be utilised a post-exercise strategy to enhance mitochondrial adaptations to exercise, in addition to its use as recovery intervention per se. Given the recent findings demonstrating improved mitochondrial adaptations following passive and post-exercise heat exposure in cell cultures and rodents, future investigations should examine the effects of post-exercise CWI on muscle oxidative adaptations to heat acclimation.

**References**

1. Burdon CA, Hoon MW, Johnson NA, Chapman PG, O'Connor HT. 2013. The effect of ice slushy ingestion and mouthwash on thermoregulation and endurance performance in the heat. International Journal of Sport Nutrition and Exercise Metabolism 23(5): 458-469
2. Corbett J, Neal RA, Lunt HC, Tipton MJ. 2014. Adaptation to heat and exercise performance under cooler conditions: a new hot topic. Sports Medicine 44(10): 1323-31
3. Hargreaves M. 2008. Physiological limits to exercise performance in the heat. Journal of Science and Medicine in Sport 11: 66-71
4. Ihsan M, Markworth JF, Watson G, Choo HC, Govus A, Pham T, Hickey AJ, Cameron-Smith D, Abbiss CR. 2015. Regular post-exercise cooling enhances mitochondrial biogenesis through AMPK and p38 MAPK in human skeletal muscle. American Journal of Physiology Regulatory, Integrative and Comparative Physiol 309(3): R286-94
5. Ihsan M, Watson G, Abbiss CR. 2016. What are the physiological mechanisms for post-exercise cold water immersion in the recovery from prolonged endurance and intermittent exercise? Sports Medicine. Epub ahead of print
6. Ihsan M, Watson G, Choo HC, Lewandowski P, Papazzo A, Cameron-Smith D, Abbiss CR. 2014. Postexercise muscle cooling enhances gene expression of PGC-1alpha. Medicine and Science in Sports and Exercise 46: 1900-1907
7. Minett GM, Duffield R, Billaut F, Cannon J, Portus MR, Marino FE. 2013. Cold-water immersion decreases cerebral oxygenation but improves recovery after intermittent-sprint exercise in the heat. Scandinavian Journal of Medicine and Science in Sports 24(4): 656-66
8. Pointon M, Duffield R, Cannon J, Marino F. 2012. Cold water immersion recovery following intermittent-sprint exercise in the heat. European Journal of Applied Physiology 112(7): 2483-94
9. Ross M, Abbiss C, Laursen P, Martin D, Burke L. 2013. Precooling methods and their effects on athletic performance. Sports Medicine 43: 207-25
10. Schlader ZJ, Stannard SR, Mündel T. 2011. Exercise and heat stress: performance, fatigue and exhaustion - a hot topic. British Journal of Sports Medicine 45: 3-5
11. Stevens C, Thoseby B, Sculley D, Callister R, Taylor L, Dascombe B. 2015. Running performance and thermal sensation in the heat are improved with menthol mouth rinse but not ice slurry ingestion. Scandinavian Journal of Medicine and Science in Sports. Epub ahead of print
12. Tamura Y, Matsunaga Y, Masuda H, Takahashi Y, Terada S, Hoshino D, Hatta H. 2014. Post-exercise whole-body heat stress additively enhances endurance training-induced mitochondrial adaptations in mouse skeletal muscle. American Journal of Physiology Regulatory, Integrative and Comparative Physiology 307: R931-943

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## Cold fluid ingestion extends exercise capacity of heat-sensitive individuals with Multiple Sclerosis in a warm environment

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**Introduction**
Exposure to a hot environment or heat gained during exercise can elicit a transient worsening of clinical symptoms in person with multiple sclerosis (MS), a demyelinating disease of the central nervous system. Heat-related fatigue has been reported in 90% of individuals with MS, potentially limiting physical activity. Therefore, simple interventions that mitigate heat-related reductions in exercise capacity in persons with MS are needed. Our aim was to test the hypothesis that cold fluid ingestion prolongs exercise duration of individuals with relapsing-remitting MS cycling in a warm (30°C, 35% RH) environment.

**Methods**
On two randomized occasions, 8 participants (49 ± 10 y; 76.4 ± 10.1 kg; 1.71 ± 0.1 m) diagnosed with relapsing-remitting MS exercised at a low intensity (~40%$VO_2$max; heat production: 3.2 ± 0.5 $W\cdot kg^{-1}$) for a maximum of 60 min (or until exhaustion), while ingesting a 3.2 $mL\cdot kg^{-1}$ aliquot every 15 min of either cold (1.5°C: CLD) or thermoneutral (37°C: NEU) water. Rectal (Tre) and mean skin (Tsk) temperature was continuously measured.

**Results**
Exercise duration was significantly longer (P=0.005) in the CLD trial (47.7 ± 15.2 min) compared to the NEU trial (34.8 ± 10.1 min). Indeed, after 45-min of exercise, 3 of 8 participants remained in NEU, whereas 6 of 8 participants remained in CLD. All subjects were able to complete a minimum of 31 minutes of exercise. At this time point, absolute Tre (CLD: 37.13 ± 0.32°C, NEU: 37.08 ± 0.31°C; P = 0.73), the change in Tre (CLD: 0.24 ± 0.25°C, NEU: 0.25 ± 0.15°C; P =0.75), absolute Tsk (CLD: 34.38 ± 0.44°C, NEU: 34.31 ± 0.30°C; P = 0.47), and the change in Tsk (CLD: 1.21 ± 0.67°C, NEU: 1.46 ± 0.46°C; P = 0.11) were all similar between CLD and NEU. Additionally, at the termination end-point of exercise, absolute Tre (CLD: 37.24 ± 0.28°C, NEU: 37.34 ± 0.38°C; P = 0.39), the change in Tre (CLD: 0.39 ± 0.25°C, NEU: 0.44 ± 0.21°C; P =0.70), absolute Tsk (CLD: 34.54 ± 0.52°C, NEU: 34.53 ± 0.44°C; P = 0.89), and the change in Tsk (CLD: 1.58 ± 0.85°C, NEU: 1.65 ± 0.88°C; P = 0.72) were all similar between CLD and NEU.

**Conclusion**
During physical activity in a warm environment, heat-sensitive individuals with MS exercised for ~35% longer before exhaustion with the ingestion of a cold compared to a thermoneutral fluid.

# The effect of crushed ice ingestion on endurance performance and cognitive function in hot and humid conditions

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## Introduction

Hot and humid conditions result in an increase in core temperature ($T_c$), which is a major limiting factor of exercise performance[1,2]. It has also been reported that heat stress can lead to significant deficits in accuracy of complex cognitive tasks such as visual search, as well as impair more simple tasks, such as reaction time[3]. Crushed ice ingestion is an effective pre-cooling method to reduce $T_c$, thus possibly leading to improved cycle time trial (CTT) performance in hot conditons[4]. Also, a reduction in $T_c$ can delay the rise in brain temperature, which may subsequently improve neural activity and therefore cognitive function during exercise in the heat[5]. The aim of this study is to analyse whether crushed ice ingestion can improve endurance performance and choice reaction time (CRT) in hot conditions.

## Methods

Nine well-trained male endurance athletes with a mean age (24±4y), height (180.4±9.9cm) and body mass (BM; 75.56±8.58kg) participated in two sessions. Prior to completing an 800 kJ CTT in the heat (34.2±0.9°C, 52.9±8.1%RH), participants consumed either 7g.kg$^{-1}$ BM of water (CON) or crushed ice (ICE). A CRT task was completed pre, during and post the CTT. Ice ingestion significantly reduced $T_c$ (-0.56±0.44°C, p=0.002) over the 30 min pre-cooling period and remained lower than CON for the first 200 kJ of the CTT.

## Results

Mean power output improved by 7.8% following ICE compared to CON (p=0.011). A significant improvement in CRT was recorded over CTT (p=0.036), and although no significant differences in CRT were recorded between conditions (p=0.421), a moderate effect size (d=0.6) indicated ICE CRT may be faster than CON at 800 kJ.

## Conclusions

Ice ingestion significantly reduced preliminary $T_c$ coinciding with improved endurance performance. However, it is still inconclusive if pre-cooling with crushed ice ingestion improves cognitive processing during exercise in the heat.

## References

1. Kraning KK, Gonzalez RR. Physiological consequences of intermittent exercise during compensable and uncompensable heat-stress. Journal of Applied Physiology 1991; 71(6):2138-2145.
2. Nielsen B. Olympics in Atlanta: A fight against physics. Medicine and Science in Sports and Exercise 1996; 28(6):665-668.
3. Maric J, Marjanovic M, Jovanovic D, Stojanovic F, Vukmirovic D, Jakovljevic V. Simple and complex cognitive functions under exertional heat stress. Serbian Journal of Experimental and Clinical Research (2015); 16(1):21-25.
4. Ihsan M, Landers G, Brearley M et al. Beneficial effects of ice ingestion as a precooling strategy on 40-km cycling time-trial performance. International Journal of Sports Physiology and Performance 2010; 5(2):140-151.
5. Mariak Z, White MD, Lewko J et al. Direct cooling of the human brain by heat loss from the upper respiratory tract. Journal of Applied Physiology 1999; 87(5):1609-1613.

# Crushed ice ingestion does not improve female cycling time trial performance in the heat

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**Introduction:** Evidence suggests that pre-cooling with ice ingestion may be effective at improving endurance performance in hot conditions in male athletes[2,4]. However, gender differences may affect physiological responses and potential performance improvements[1,3,5]. Therefore, this study aimed to assess the effects of pre-cooling with ice ingestion on female cycling performance. It was hypothesised that ice ingestion would improve cycling performance, delay the onset of sweating and increase RER and $VO_2$ towards the end of the cycle time-trial.

**Methods:** Ten female endurance athletes, mean age (28±6 y), height (167.6±6.5 cm) and body-mass (68.0±11.5 kg) participated in the study. Participants completed an 800 kJ cycle time-trial in hot, humid conditions (34.9±0.3°C, 49.8±3.5% RH). This was preceded by the consumption of 7 $g\cdot kg^{-1}$ of crushed ice (ICE) or water (CON). Trials were randomised and completed a week apart, at the same time of day. The ventilated capsule method was used for the measurement of sweat onset and sweat rate. Expired air was collected and fed through a metabolic cart to analyse oxygen and carbon dioxide content.

**Results:** There was no difference in performance time (CON 3851±449 s; ICE 3767±465 s), oxygen consumption (CON 41.6±7.0 $mL\cdot kg\cdot min^{-1}$; ICE 42.4±6.0$mL\cdot kg\cdot min^{-1}$) or respiratory exchange ratio (CON 0.88±0.05; ICE 0.90±0.06) between conditions ($p>0.05$). Core temperature decreased following pre-cooling with ICE (-1.0±0.4°C) compared with CON (-0.2±0.2) and remained lower until the 100 kJ mark of the cycle time-trial ($p<0.05$, $d>1.0$). Sweat onset occurred earlier in CON (228±113 s) compared with ICE (411±156 s) ($p<0.05$, $d=1.63$). Mean thermal sensation ($p<0.05$, $d=2.51$), perceived exertion ($p<0.05$, $d=0.38$) and perceived thirst ($p<0.05$, $d=0.98$) were lower in ICE compared with CON.

**Conclusion:** Crushed ice ingestion did not improve cycling performance in females even with a significant reduction in core temperature. However, reduced perceptual responses suggests participants were more comfortable in the heat when pre-cooling.

**References**

1. Gagnon, D., Dorman, L. E., Jay, O., Hardcastle, S., & Kenny, G. P. (2009). Core temperature differences between males and females during intermittent exercise: physical considerations. European Journal of Applied Physiology, 105(3), 453-461.
2. Ihsan, M., Landers, G., Brearley, M., & Peeling, P. (2010). Beneficial effects of ice ingestion as a precooling strategy on 40-km cycling time-trial performance. International Journal of Sports Physiology and Performance, 5, 140-151.
3. Kaciuba-Uscilko, H., & Grucza, R. (2001). Gender differences in thermoregulation. Current Opinion in Clinical Nutrition and Metabolic Care, 4(6), 533-536.
4. Yeo, Z. W., Fan, P. W. P., Nio, A. Q. X., Byrne, C., Lee, J. K. W., Medical, D., . . . Kingdom, U. (2012). Ice Slurry on Outdoor Running Performance in Heat. International Journal of Sports Medicine, 33(11), 859-866.
5. Wright, A., Marino, F. E., Kay, D., Micalos, P., Fanning, C., Cannon, J., & Noakes, T. D. (2002). Influence of lean body mass on performance differences of male and female distance runners in warm, humid environments. American Journal of Physical Anthropology, 118(3), 285-291.

## Caffeinated ice slushy enhances endurance cycle performance in hot, humid conditions

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**Introduction**
Pre-cooling via ice ingestion has consistently shown improved endurance exercise performance in the heat by reducing pre-exercise core temperature. Caffeine has also shown improvement in endurance performance but currently it is unclear if the combination of caffeine with ice ingestion could improve performance further. The aim of this investigation was to determine the effects of a low dose of caffeine ingested as part of a carbohydrate ice slushy on cycling time trial performance in hot, humid conditions.

**Methods**
Ten well trained male cyclists or triathletes ingested 6.8 $g{\cdot}kg^{-1}$ crushed ice with either: a 6% concentration of carbohydrates only (CON) or 6% carbohydrates and 3 $mg{\cdot}kg^{-1}$ caffeine (CAF) over a 30 min period prior to exercise in a single-blind, counterbalanced design. Participants completed two cycling time-trials (CTT) equating to 1200 kJ of work, in a climate controlled chamber (33°C, 60% RH), each separated by seven days. During each CTT, rectal temperature ($T_{re}$), cycling time, mean power output (MPO), heart rate (HR), blood lactate (BLa), ratings of perceived exertion (RPE) and thermal sensation (RPTS) were measured at set intervals of work.

**Results**
A faster (4.0%) CTT was completed and a higher MPO was recorded by CAF (260.9±42.0 W) compared to CON (249.3±35.5 W) condition ($p=0.007$). Participants cycled faster during the second half of the CTT in CAF (2342±399 s) compared to the CON (2495±354 s; $p=0.002$). Pre-cooling lowered $T_{re}$ equally in both conditions ($p<0.05$) prior to cycling. No significant difference existed between conditions for, RPE, RPTS, HR or BLa at any time point.

**Conclusion**
Crushed ice ingestion was effective in lowering $T_{re}$ prior to exercise and the addition of caffeine resulted in a performance benefit. However, most improvement occurred during the second half of the CTT, thus if caffeine ingestion occurred earlier than 30 min pre-exercise, greater benefits may result.

*Friday 9th September*
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## Short-term heat acclimation and the lactate threshold

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**Introduction**
Athletes often seek the minimum required time that might elicit a physiological or performance change. It is reasonable to suggest that heat training may improve aerobic-based performance in mild conditions[1,2,3]. Therefore, rather than providing a traditional heat exposure stimulus (i.e. 7-10 x 60-100 min sessions), the current research details two studies that aimed to determine the effect of brief (≤240 min of exposure) heat training upon the second lactate threshold ($LT_2$) in mild conditions.

**Methods**
Forty-one participants completed five (Study 1; n=18) or four (Study 2; n=23) perceptually-regulated treadmill exercise training sessions in 35 °C and 30% relative humidity (experimental group) or 19 °C and 30% relative humidity (control group) conditions. Pre- and post-incremental exercise testing occurred in mild conditions (19 °C and 30% relative humidity). Linear mixed effects models analysed the change in $LT_2$. Effect sizes (Cohen's $d$) were calculated and significance was set at $p$<0.05.

**Results**
Heat training did not substantially change $LT_2$ in either Study 1 (+1.2%, $d$=0.38, $p$=0.248) or Study 2 (+1.9%, $d$=0.42, $p$=0.163). The $LT_2$ was not substantially changed in the control group in Study 1 (+1.3%, $d$=0.43, $p$=0.193), but a within-group change was evident in Study 2 (+2.3%, $d$=1.04, $p$=0.001).

**Conclusion**
The studies indicated that brief heat training was inadequate to improve the speed at $LT_2$ in mild conditions to a greater extent than comparable training in mild conditions. The brief nature of the heat training protocol did not allow adaptations to develop to the extent required to potentially confer a performance advantage in an environment that is less thermally stressful than the training conditions.

**References**
1. Chalmers S, Esterman A, Eston R, Bowering KJ, Norton K. 2014. Short-term heat acclimation training improves physical performance: a systematic review, and exploration of physiological adaptations and application for team sports. Sports Medicine. 44(7):971-88.
2. Corbett J, Neal R, Lunt H, Tipton M. 2014. Adaptation to Heat and Exercise Performance Under Cooler Conditions: a New Hot Topic. Sports Medicine. 44(10):1323-31.
3. Minson C, Cotter J. 2016. CrossTalk proposal: Heat acclimatization does improve performance in a cool condition. The Journal of Physiology. DOI: 10.1113/JP270879.

# Thermal effect of topical menthol on short duration cycling performance in the heat

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## Introduction
It has been demonstrated that application of menthol reduces thermal sensation (TS) during exercise in the heat[1,2,4]. However, lower TS has not translated to improved endurance performance[1,2]. Whether a lower TS can have an effect on performance during short duration high-intensity cycling in the heat has not been investigated. Therefore, the purpose of this study is to investigate the effects of topical menthol application to the lower extremities on performance during a 2-min cycling time-trial (TT). It is hypothesised that menthol will lower TS and improve TT performance.

## Methods
Fifteen recreationally active males (n=5) and females (age: 25.1±8.8y, height: 1.72±0.8m, mass 67.9±8.8kg) completed a familiarisation TT followed by three randomised TTs (control, placebo and menthol) on a Wattbike ergometer (Wattbike Ltd, UK). TTs were completed at the same time of day (±2h) with a minimum of 24h between trials. Power and heart rate were recorded instantaneously and averaged over 30s intervals with $TS_{body}$ and $TS_{legs}$ collected at 30, 60, 90 and 120s. Distance covered in each TT was compared using a one-way ANOVA. A two-way ANOVA (condition x time) was used to analyse 30s interval data.

## Results
No differences ($p=0.463$) were observed in distance covered between control (1430±140m), placebo (1440±140m) and menthol conditions (1440±120m). $TS_{legs}$ was significantly different ($p<0.0001$) between conditions (control>placebo>menthol) and $TS_{body}$ was lower than control during the menthol TT ($p=0.026$). A significant interaction ($p=0.008$) for $TS_{legs}$ was observed.

## Conclusion
While perceptual variables have been shown to influence performance[3] lower $TS_{legs}$ and $TS_{body}$ after menthol application had no effect on TT performance.

## References
1. Barwood MJ, Corbett J, Thomas K, Twentyman P. 2015. Relieving thermal discomfort: Effects of sprayed L-menthol on perception, performance, and time trial cycling in the heat. Scandinavian Journal of Medicine and Science in Sports 25:211-8.
2. Barwood MJ, Corbett J, White D, James J. 2011.The influence of thermal perception change using L-menthol on pacing regulation during exercise in the heat. British Journal of Sports Medicine 45:A2.
3. Cheung SS. 2010. Interconnections between thermal perception and exercise capacity in the heat. Scandinavian Journal of Medicine & Science in Sports 20:53-59.
4. Gillis DJ, House JR, Tipton MJ. 2010. The influence of menthol on thermoregulation and perception during exercise in warm, humid conditions. European Journal of Applied Physiology 110:609-18.

## Effect of Kinesio Tape on thermoregulation during submaximal cycling: a pilot study

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### Introduction
Kinesio Tape (KT) is a relatively new product targeted to prevent and treat musculoskeletal injuries and enhance performance. However, comprehensive taping reduces surface area exposed, potentially increasing heat retention due to reduced evaporative sweat rate [1-3], and negatively affecting exercise performance[4]. This study examines the effects of KT application on thermoregulation during submaximal cycling. It is hypothesised that KT will impair thermoregulation indicated by higher tympanic temperature ($T_t$), thermal sensation (TS), and lower sweat loss.

### Methods
Ten healthy males and females (5 males; mean±SD; age: 25±6 y, height 1.72±0.07 m, body mass 66.3±7.2 kg) cycled for 45-minutes at 60% of peak power output (144±28 W) using a randomised cross-over design on a Lode ergometer (taped and non-taped at 30°C and 50% RH). KT was applied according to Rocktape™ guidelines for cycling performance. Heart rate (HR), rating of perceived exertion (RPE), $T_t$ and TS were measured at 5-minute intervals. Pre and post-exercise body mass was measured to estimate sweat loss. Intermittent measures were compared using repeated measures 2-way ANOVA. Pre and post-exercise measures were compared with a paired T-test. Effect sizes (ES) were calculated between conditions.

### Results
No significant interaction ($P>0.05$) in HR, RPE, $T_t$, and TS was found between taped and non-taped conditions. However, moderate effect sizes for $T_t$ (ES=0.8) and TS (ES=0.6) occurred at end exercise. Sweat loss was significantly higher ($P=0.03$) during the taped condition (0.81±0.16kg) compared to the non-taped condition (0.71±0.13kg).

### Conclusion
KT does not influence HR, RPE, Tt and TS during 45-minutes submaximal cycling in hot/humid conditions, but may contribute to greater sweat loss. Moderate ES between conditions at end exercise for TS and Tt, in conjunction with greater sweat loss, suggests KT may increase heat retention during prolonged exercise. Further research should consider longer duration exercise where greater thermoregulatory demands may occur.

### References
1. Gavin TP. Clothing and thermoregulation during exercise. Sports Medicine. 2003; 33(13):941-947.
2. Nagata H. Evaporative heat loss and clothing. Journal of Human Ergology. 1978; 7(2):169-175.
3. Brownlie L, Mekjavc I, Banister E. Thermoregulation in athletic racing apparel. The Annals of Physiological Anthropology. 1987; 6(3):145-155.
4. Hargreaves M. Physiological limits to exercise performance in the heat. Journal of Science and Medicine in Sport. 2008; 11(1):66-71.

# Pre-match and half-time-cooling on simulated soccer (iSPT) performance at 30°C

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**Introduction**
Elite soccer played in hot environments can hinder physical performance when compared to a temperate environment. Elevated skin temperature ($T_{sk}$: r = 0.82, $p$ = 0.02) and thermal sensation (TS: r = 0.82, $p$ = 0.05) during simulated soccer predict these heat-induced-decrements[1] . Match-play data (30°C) revealed 20 min of mixed-method pre-match and 5 min half-time-cooling blunted rises in TS and rectal ($T_{re}$) temperature with a moderate performance effect (d= 0.6) on high-speed distance (HSD) covered[3]. However, high match-to-match variation for key physical performance measures in match-play, makes ascertaining the meaningful inferences from cooling interventions problematic[4]. Therefore, this study investigated the effects of various pre-match and half-time-cooling strategies on simulated soccer performance at 30 °C; 50% rH by using a laboratory based soccer-specific simulation [intermittent soccer performance test (iSPT)[2]].

**Methods**
On four separate occasions, eight University soccer players completed four randomised trials of iSPT at 30 °C; 50% rH, following one of four 30-min (pre-match) and 15 min (half-time) cooling interventions: (1) ice slurry ingestion (SLURRY); (2) ice packs on the upper legs; (3) mixed-methods (MM) using PACKS and SLURRY concurrently; or (4) No-cooling (CON).

**Results**
After MM pre-match-cooling, all physical performance measures [total distance (3%), HSD (4%) and variable run distance (5%) covered] were significantly improved in the first half due to TS, $T_{re}$ and $T_{sk}$ all being significantly reduced compared with CON. However, physical performance, body temperatures and TS were unchanged in the second half after MM half-time-cooling compared with CON. No changes were evident in PACKS and SLURRY.

**Discussion**
The ergogenic effect seen in the first half of MM was likely due to both peripheral ($T_{sk}$) and central ($T_{re}$) factors, which are responsible for the heat-induced-decrements seen in soccer, being targeted[1]. The minimal effect that MM half-time-cooling had on second half performance may be due to an appropriate volume of cooling not being utilised at half-time, as a large amount of heat is stored within the body's periphery from the first half[3]. Therefore, although 30 min of MM pre-match-cooling improves simulated soccer performance during the first half. Future research should identify a valid half-time-cooling strategy to improve soccer performance in the second half.

**References**
1. Aldous, J.W., B.C. Chrismas, I. Akubat, B. Dascombe, G. Abt, and L. Taylor, Hot and Hypoxic Environments Inhibit Simulated Soccer Performance and Exacerbate Performance Decrements When Combined. Frontiers in Physiology, 2016. 6: 421.
2. Aldous, J.W.F., I. Akubat, B.C.R. Chrismas, S.L. Watkins, A.R. Mauger, A.W. Midgley, G. Abt, and L. Taylor, The Reliability And Validity Of A Soccer-Specific Nonmotorised Treadmill Simulation (Intermittent Soccer Performance Test). Journal of Strength and Conditioning Research, 2014. 28(7): 1971-1980.
3. Duffield, R., A. Coutts, A. McCall, and D. Burgess, Pre-cooling for football training and competition in hot and humid conditions. European Journal of Sport Science, 2013. 13(1): 58-67.
4. Gregson, W., B. Drust, G. Atkinson, and V.D. Salvo, Match-to-match variability of high-speed activities in premier league soccer. International Journal of Sports Medicine, 2010. 31(4): 237-42.

*Friday 9th September*
*Chairperson: Glen Deakin*
*Room 1 – Raffles*

## Effects of heat on sports performance

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Coaches, athletes and support personnel seek information on the effects of heat and humidity on sports performance. This information is valuable for prescribing and managing the training of athletes and teams, preparation for competition day and recovery strategies, and developing policies, guidelines and education materials. The likely negative effect of high ambient temperature and humidity on sports performance is well understood by the sporting community, but not all sports and events are affected to the same degree. Performance in some shorter, faster and more explosive events may actually be improved by warm to hot conditions. Similar to other environmental stressors, the effects of heat stress appear to be task and severity dependent. The importance of differentiating tasks (sports) into categories of single effort, repeat effort and intermittent activities in relation to heat stress is emerging. The majority of studies have examined performance and classical physiological markers of thermoregulation and heat stress including core and skin temperature, heart rate and sweat rate. Contemporary physiological models integrate regulation of temperature-dependent muscle contractility with cardiovascular and metabolic strain. A small number of studies have also examined the effects of heat stress and dehydration on perceptual cues (thermal sensation), mood state, and cognitive decision making that might be important in both individual and team sports. Ambient conditions that should be monitored in both training and competition settings include temperature, relative humidity, wind speed and solar radiation. Underlying fitness, prior exposure to heat and heat training, voluntary or permissive dehydration during training, pre-cooling strategies, hydration strategies, clothing and protective equipment can influence the degree of heat stress experienced by individuals. Other sports-specific considerations include modification of pacing strategies and, in team sports, changes in tactics and activity patterns to mitigate heat stress. Development of effective heat training strategies should address physiological, environmental, cognitive and tactical factors.

*Friday 9th September*
*Chairperson: Ollie Jay*
*Room 2 – Kingston*

## Military training in hot environments: Identifying future directions to enhance individual health and physical performance.

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**Introduction**
The effects of heat exposure on the human body can have disastrous consequences for the unsuspecting and unprepared individual. The cumulative stress of heavy physical workloads combined with protective clothing systems and harsh environmental conditions raises physiological strain to the limits of human tolerance during military training and operational activities. Heat-related illnesses develop and include symptoms such as fatigue, weakness, dizziness, confusion, and fainting; and consequently personnel become incapacitated by heat exhaustion. In more severe cases, an excessive elevation in the body's core temperature impairs central nervous system function and causes body tissue damage. Therefore, preventing these heat-related illnesses is not only crucial to the health of the individual but also in maintaining the operational capability of the defence forces.

**Heat Illness Prevention Strategy**
To mitigate the risk of heat-related illnesses, military training activities are conducted in accordance with a policy framework for working in the heat. A key element of the framework is known as a Work Table; a tool that sets limits to the duration of work periods, and prescribes minimum durations for recovery periods, dependant on the environmental conditions, the work intensity, and the protective clothing worn by personnel[5]. The work duration limits implemented by the Australian Army are based on the assumption that an elevation in body core temperature of 1.5 °C, from 37.0-38.5 °C, will occur over the course of the work period. This assumption takes into account that when the average soldiers' body core temperature reaches 38.5 °C, most individuals would be in the range of 38.0-39.0 °C, with a small proportion of personnel rising above 39.0 °C by the end of the work period. The implementation of these physiological assumptions through the Work Table work duration limits aims to minimise both the risk of heat exhaustion and to prevent any soldier experiencing an excessive elevation in body core temperature.

**Inter-Individual Variability in Heat Strain**
A criticism of the Work Table approach has been its perceived constraint on the conduct of effective military training. Stemming from the physiological assumptions that are based on the population average, the majority of personnel are thought to be prevented from training to their full potential under the Work Table guidance. Indeed, the inter-individual variability in body core temperature responses to military activities is large, ranging from a change from baseline of 0.4 – 2.5 °C during a 5 km march at best pace (without running) while carrying 40 kg of external load[2]. Furthermore, when soldiers performed military training (a 10 km march at 5.5 km·h$^{-1}$ carrying 40 kg of external load) in conditions slightly above the Work Table guidance, participants that demonstrated a high elevation in body core temperature were not associated with those participants for whom symptoms of heat-related illness caused them to withdraw from the activity[4]. These findings highlight two important implications for mitigating the risks of heat-related illness: firstly, the protection provided by Work Table limits may be conservative, thereby constraining a commander's mandate to develop an optimised military force by mitigating risk for all personnel according to the least heat tolerant personnel. Secondly, the dissociation between heat-related symptoms and body core temperature elevation suggests that setting work duration limits based on a single indicator of thermal strain (body core temperature) is not accurately identifying at-risk individuals. Therefore, strategies need to be developed that can balance the competing demands of ensuring adequate protection against heat-related illness and the conduct of effective training in hot environments.

**Future Directions**
Technological advances have seen the development of sensors with increased capability through prolonged battery life, miniaturization to reduce load carriage, and reduced costs; which translate into the ability to implement these sensors in a real world environment. These advances have brought the prospect of real-time physiological status monitoring into the sights of military commanders as they seek to utilise technologies that will enhance their operational capability through actionable feedback of physiological status[3]. Research is beginning to show that guidance based on feedback from individual physiological responses is able to improve pacing strategies and reduce

thermal strain during work in the heat[1]. Further research is required to validate indices of physiological strain that most accurately predict tolerance to work in the heat and to establish the utility of these indices to inform, in real-time, the optimal personnel management strategies during training and operations.

**Conclusion**

Preventing heat-related illnesses is crucial to the health of the individual and the operational capability of the military. The Work Tables are a risk management tool that sets limits to the duration with an aim to minimise both the risk of heat exhaustion and to prevent any soldier experiencing an excessive elevation in body core temperature. While this strategy manages risk at a population level, individual responses to work in the heat vary considerably and are not accurately detected by the current guidance without unnecessarily constraining the whole workforce. The development of real-time physiological status monitoring capabilities has the potential to achieve a balance between protecting soldiers from the risk of heat-related injury whilst also achieving effective training outcomes.

**References**


1. Buller, M. J., A. P. Welles, M. Stevens, J. Leger, A. Gribok, O. C. Jenkins, K. E. Friedl and W. Rumpler (2015). Automated guidance from physiological sensing to reduce thermal-work strain levels on a novel task. Body Sensor Networks Conference 2015. Cambridge, USA.
2. Fogarty, A., A. Hunt, D. Billing and M. Patterson (2013). Comparison of Measured and Predicted Body Core Temperature during a 5-km March. Proceedings of the 15th International Conference on Environmental Ergonomics, Queenstown, New Zealand, International Society for Environmental Ergonomics.
3. Friedl, K. E., M. J. Buller, W. J. Tharion, A. W. Potter, G. L. Manglapus and R. Hoyt (2016). Real Time Physiological Status Monitoring (RT-PSM): Accomplishments, Requirements, and Research Roadmap. Natick, MA, United States Army Research Institute of Environmental Medicine.
4. Hunt, A. P., D. C. Billing, M. J. Patterson and J. N. Caldwell (2016). "Heat strain during military training activities: The dilemma of balancing force protection and operational capability." Temperature 3(2):1-11.
5. Sawka, M. N. and K. B. Pandolf (2001). Physical Exercise in Hot Climates: Physiology, Performance, and Biomedical Issues. Medical Aspects of Harsh Environments. K. B. Pandolf and R. E. Burr. Washington, Borden Institute**:** 87-133.

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